THE IMPACT OF ALTERNATIVE MARKETING ARRANGEMENTS ON THE PERFORMANCE OF PROCESSING COOPERATIVES

By

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To my parents

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The thrust of this study concerned a theoretical and empirical assessment of the impact of alternative marketing arrangements on the performance of processing cooperatives. The main distinction made between a pure marketing cooperative and a processing cooperative was the existence of a fixed cooperative plant.

The theoretical framework involved modeling of two types of members' behavior: (1) individualistic or "myopic" behavior where members strive to maximize only their own net returns and (2) coordinated behavior that leads to a Pareto optimal solution where total and individual profits are maximized. The model was extended to allow for variable raw product characteristics and heterogeneous members. It was concluded that a preferred coordinated solution can be attained by inducing compliance through quotas and individualized penalties and rewards that can be embodied in payment policies.

The empirical procedures involved a mathematical programming model applied to sugarcane processing cooperatives in Florida. This model was conceptualized as having two strata of decision making: (1) the level at which policies are set and (2) that at which a member maximizes own net returns taking policies set at level 1 and other members' actions as given. Although the resulting problem was large and data intensive, it was manageable. To operationalize the model, the parameters were estimated by statistical models and the resulting problem was solved as a network flow.

The empirical results reinforced the internal validity of the theoretical model. For instance, a coordinated sugarcane cooperative made net returns that were twice as large as those attained by a cooperative where members' raw product was pooled and the members behaved individualistically. The use of processing quotas tended to equalize members' net returns and in some cases increased coordination. Overall, it was concluded that if members behave individualistically and not in the collective interest, the achievement of preferred performance outcomes must be devised through policies at the individual level--the particular level of their response.

CHAPTER I

INTRODUCTION

A cooperative association is a coalition of firms that pursues economic activities for the benefit of its members. Farmer cooperatives are usually classified, depending on the vertical position of such activities, into marketing cooperatives and (input) supply cooperatives.

The agricultural economics literature has not distinguished between processing cooperatives and pure marketing cooperatives. In addition to buy-sell and first-handler operations, processing cooperatives internalize the processing of the raw product supplied by the patrons by altering its form. This encompasses a greater dominion of a value-added system than pure marketing cooperatives. Since integration is costly and capital intensive, by extending downstream boundaries these cooperatives involve higher capital investment. This increases the likelihood of limited processing plant capacity and of inflexibility in membership, financial, marketing and organizational policies.

Processing cooperatives in the U.S. are important in agricultural activities such as sugarcane, citrus, fruits and vegetables, dairy and poultry. For instance, processing cooperatives in California handle 85 percent of Freestone peaches, 60 percent of spinach, 60 percent of apricots and 25 percent of tomato volumes (Garoyan, 1979). In the U.S. dairy sector in 1973, cooperatives processed 28 percent of the milk volume (O'Day, 1978).

Two factors are likely to enhance the future importance of processing cooperatives. One is the continuation of the past growth trend in agricultural cooperatives which has been one of the most rapid structural development in the U.S. farming sector in recent decades.[1] Second is the increase of forward integration from producers-first handler activities which is essential for the future survival of marketing cooperatives (Kraenzle et al., 1979).[2] However, as farmer cooperatives attempt to forward integrate into the processing segments of the U.S. food industries, they will undoubtedly face entry barriers in which financial and operational sophistication is needed.

The impressive growth of the agricultural cooperatives has expanded the set of questions among policy makers and agricultural economists about the impact of agricultural cooperatives on members' income, output level, consumer prices and overall performance (e.g., Lang et al., 1982, and Vitaliano and Condon, 1982).[3] At the same time, the growth in cooperative theory and studies has less than matched the growth of cooperatives and the increasing concern about them. Vitaliano and Condon (1982) identified three important questions relating to further

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[1]The importance of these organizations in the metamorphosis of the U.S. agricultural industry is reflected by the fact that in the 25 year period from 1950 to 1975, agricultural cooperatives increased their share of cash receipts of products marketed at the first-handler level from 20 percent to nearly 30 percent (USDA, 1977).

[2]These authors also indicate other reasons for cooperatives to forward integrate such as the enhancement of their share of the consumer dollar, the protection of members' markets, and the enhancement of their members' bargaining strength.

[3]These questions were raised and discussed in a 1977 workshop of the North Central Regional Research Committee 117 under the topic "Agricultural Cooperatives and the Public Interest."

developments of cooperative theory: (1) internal organization of the cooperative and the objective of the participants, (2) information, monitoring and control of cooperatives, and (3) technical and organizational efficiency of cooperatives.

The Problem

The foregoing suggests the need for research dealing with organizational and behavioral aspects of cooperatives. Clearly, the set of arrangements among cooperative members constitutes the core of the cooperative structure along which resource allocation is guided, therefore constituting an important determinant of their performance. Even though these arrangements replace the mechanism of open market forces for a raw product, they retain the role as prime coordinator of marketing and production among the decision units.

A conflict-free or harmonious cooperative operation is rarely, if ever, the case. The likelihood of conflict increases as the degree of downstream integration increases, making conflict issues of foremost importance to processing cooperatives. The conflicts are settled in part by contractual arrangements, which are essential instruments of coordination among the members in order to achieve their objectives. To the degree that members are interdependent in the operation of the cooperative plant, arrangements among the members are essential for workable guidelines of mutual (proportional) share of benefits and responsibilities.

Arrangements among members of a processing cooperative converge to three areas: (1) payment to each member relative to the actual value or

contribution of the raw product delivered; (2) the share of a fixed processing capacity of the cooperative plant; (3) financial arrangements regarding deferred patronage refunds and other financial parameters. Below concentration is placed on the first two areas.

The role of arrangements for payment is of primary importance in providing adequate incentive and equity structures among the members. These arrangements concern the mechanism for computing payments to each member for their deliveries from the net savings of the cooperative. All cooperatives are bound morally, but not legally, by the arrangement that they must redistribute all net savings in "proportion" to the use of cooperative services (Abrahamsen, 1976). Ideally, each member should be paid in accordance to the use value of his delivery. The use value of agricultural commodities varies with quantity, quality, delivery time and distance from the processing plant.[4]

In establishing payment arrangements, cooperatives resort to pooling, a process of averaging costs and returns generated by the members. The degree of pooling affects the rationalization of raw product prices perceived by the patrons from the cooperative, since the individual in isolation does not receive the full benefit or penalty from his actions. At the farm level, quality of raw product depends upon numerous factors, including delivery time, variety of the crop,

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[4]A raw product may offer a set of quality parameters associated with the demand of the final commodity (characteristics that affect the consumer evaluation of the product) and/or quality parameters associated with the supply of the final commodity (that affect production costs). Examples of the latter are in citrus where specialty fruit costs 15 percent more to process (Polopolus and Lester, 1969) and high fiber sugarcane which increases the cost of extraction of raw sugar (Meade and Chen, 1977).

production practices and weather. A disincentive for better quality induces a lower general level of quality than when quality is explicitly compensated. An equity problem arises if raw products are co-mingled with pooling, despite the fact that individual growers may have delivered different qualities of raw product.

Cross-externalities among the members regarding the use of the processing plant result from limited processing capacity, especially when coupled with production seasonality and perishability of the product. There are two aspects regarding processing arrangements. One is the use of individual quotas among the members throughout the processing season as an instrument of "fairness." The other aspect is the sovereignty of the members in determining the volume of their delivery in the spirit of the democratic nature of cooperative institutions. This sovereignty holds also in determining the quality of the raw product delivered.

To discern the impact of alternative arrangements (structure) among cooperative members on the performance of the cooperative, one must incorporate the individual members and cooperative (group) behavior. The above situation allows a broader class of group behavior problems, in particular free riding and the cooperative analogy of the prisoner's dilemma.

Behavioral Nature of the Problem

The kernel behavioral postulate of economics is that man is egoistic, rational and a utility maximizer. Even though the basic behavioral force of increasing well-being is what induces a group of farmers to

"cooperate" by forming a cooperative association, individually they are likely to engage in independent noncooperative behavior. The resulting behavior, from a conceptual standpoint, is the analogy of the prisoner's dilemma.[5] Such behavior results from a member's dilemma when he has the incentive to "free ride" (and thus capture gains when other members are behaving for the cooperative welfare) or to "protect" himself when other members are attempting to free ride. The so-called dilemma arises because what appears to be best for an individual member, given the behavior of other members, produces a result that can be improved by "cooperation" or coordination, even if every individual prefers the mutual cooperation outcome.

Still in the twilight zone of behavioral theory is the dilemma of whether the achievement of the preferred outcome in the Prisoner's Dilemma Game is compatible with individual incentives. Hobbes' theory (1909) suggests that the only way to insure that the preferred outcome is obtained is to establish a government with sufficient power to ensure that it is in every man's interest to choose the cooperation outcome. This suggests that coercion is necessary (or that the individuals agree to be coerced) in that regard. In terms of the above problem, this would indicate a centralized management that coordinates members' deliveries so that the coordination outcome results. Coercion, however, implies the loss of members' sovereignty while tailoring of arrangements may provide a coordination mechanism among cooperative members without resorting to coercion.

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[5]Luce and Raiffa (1957) present a discussion of the classical prisoner's dilemma game.

By its nature, an arrangement is a contract, and contracts govern or regulate the exchange between parties, thus constraining their behavior. Alchian and Demsetz (1972) argue about the possibility of individuals "shirking" contractual responsibilities if benefits of doing so exceed the costs. As a case in point, they consider that mutual shirking is more likely to occur in the case of common ownership.

The problem of scanning arrangements among cooperative members is analogous to problems faced by policy makers who must account for the actions of a myriad of decentralized decision making units which take policy variables as given, but also have their own objectives. Thus, setting arrangements scenarios to scan alternative arrangements can be viewed as a hierarchical decision problem.

Objectives

The overall objective of this research is the assessment of the implications of alternative arrangements among the members of processing cooperatives through the structure-behavior-performance paradigm. More specifically, the objectives are

1. To provide a conceptual framework to investigate the behavior of processing cooperative members, and to assess the performance implications of alternative coordination arrangements among the members that may induce compliance to attain coordinated cooperative equilibria.
2. To develop an empirical harvest-processing model as a constrained optimization problem suitable to represent the arrangements among the members.

3. To illustrate the impact of alternative pricing policies, volume regulation and processing arrangements for processing cooperatives by accommodating the above models to the case of Florida sugarcane processing cooperatives.

Scope

The intended scope of this research is confined to the determination of the economic effects of alternative arrangements on the performance of processing cooperatives. This is not, however, an attempt to find the "best" arrangements for these farmer-owned organizations. The lack of any universal set of value judgments, of accurate relevant data, and the impossibility of a fully satisfactory partial solution, will prevent that.

The term "alternative" rather than "optimal" arrangements implies discretion on the formulation of arrangements scenarios. Thus the present analysis is limited to a set of policy variables in the spectrum of arrangements possibilities, to provide, perhaps, a heuristic answer to the problem. In actual situations, other considerations (e.g. social, ethical or political) may be decisive, regardless of the economic outcome. If, however, the study succeeds in making some of the central issues involved in the formulation and implementation of alternative arrangements any clearer, the scope of it is not fruitless in this unexplored area of research.

Organization of the Study

This chapter has presented an introduction to the problems posed by cooperative arrangements and has listed the objectives of the study.

The following chapter describes the economic nature of cooperative associations, emphasizing the organizational characteristics of processing cooperatives. The heritage of economic theories of cooperation is also reexamined. Then, the chapter addresses the underlying rationale and identification of alternative cooperative arrangements.

In Chapter III, the concepts behind the operational procedures of cooperatives provided in Chapter II are integrated into a conceptual processing cooperative model to explain the behavior and functioning of the cooperative and its members. The evaluation of different practices through their impact on performance is also provided.

The conceptual model developed in Chapter III is modified in Chapter IV to set up a mathematical programming model for the simulation of alternative coordination arrangements. The empirical model is applied to Florida sugarcane cooperatives for which the parameters are estimated. The model is implemented as a network flow problem.

Chapter V presents the performance results of the simulation of different arrangements such as payment based on the amount of sugarcane (raw product) delivered, payment based on the amount of sugar (finished product) delivered, coordinated (maximum total profits) cooperative operation, delivery quotas and volume regulation schemes. Performance (allocative efficiency and equity) comparisons are made, and a general assessment of results is provided.

In the last chapter, the findings of the study are summarized. Conclusions, limitations and suggestions for further research are provided for both the theoretical and empirical expositions of previous chapters.

CHAPTER II

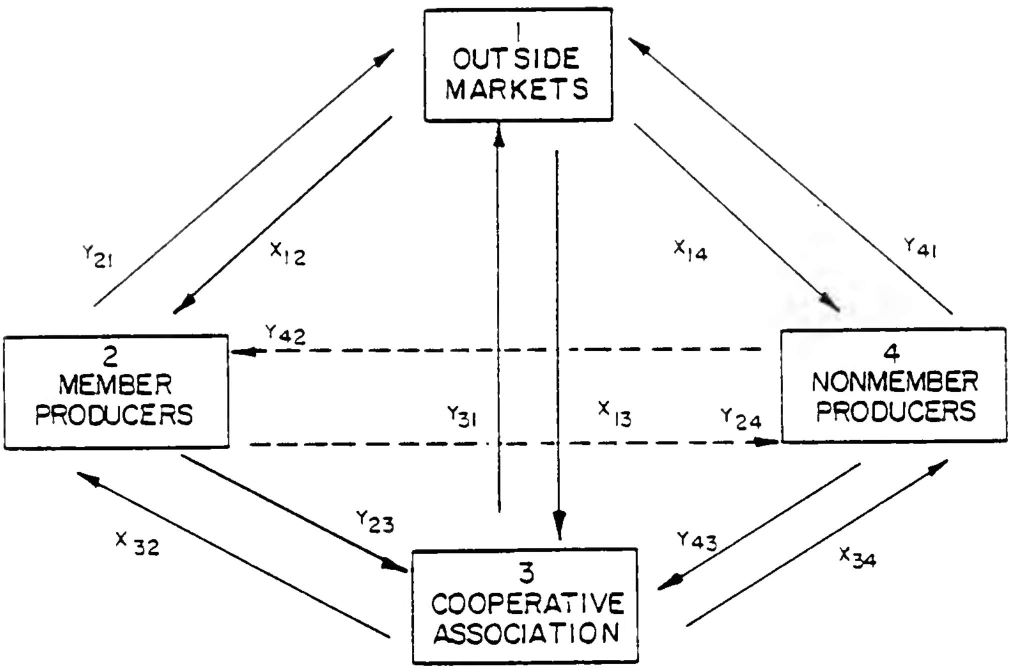
PROCESSING COOPERATIVES AND ARRANGEMENTS STRUCTURES

Despite the important and increasing role of cooperatives in the share of agricultural output, relatively few theoretical or empirical studies, and no specific studies, have been done on sugarcane processing cooperatives to date. This chapter discusses the basic concepts of cooperation. The primary objective is to aid in the understanding of the issues involved and to clear the avenues for subsequent theoretical and empirical developments.

The Cooperative Association

A cooperative association is a coalition of firms or individuals that pursue economic activities for the benefit of its members. Farmer cooperatives are usually classified in two categories according to the vertical position of such services: (1) marketing cooperatives, where the cooperative provides marketing and/or processing services to the patrons for the commodity they produce, and (2) supply cooperatives, where the cooperative provides members with one or more of the production inputs they need for their farm operations. In accordance with their horizontal nature, cooperatives can be classified as having closed or open membership depending upon whether new entry of members is restricted (closed) or not (open).

The possible configurations of cooperatively-structured businesses are summarized in Figure 2.1. Let X_{ij} and Y_{ij} denote a variable input



X_{ij} = Set of Variable Inputs

Y_{ij} = Set of Outputs

i,j= Source and End Node
= 1,2,3,4 but $i \neq j$

Figure 2.1. Inter-flows of Inputs and Outputs in a Generalized Hypothetical Cooperative Association Environment.

and a particular output flowing from node i to node j, where the nodes 1, 2, 3 and 4 are the cooperative, its members, nonmembers, and outside markets where the cooperative and producers buy or sell commodities, respectively. In a larger time span, membership adjustments can be viewed as a conceptual two-way flow: members enter (Y_{42}) and members exit (Y_{24}) from the cooperative. A closed membership cooperative would be represented by deleting Y_{42}. Marketing cooperatives operate with little or no flow along X_{32} and X_{34}, while supply cooperatives operate with little or no flow along Y_{23} and Y_{43}. X_{12}, Y_{23}, Y_{31}, and X_{13} constitute the organizational scheme of a typical processing cooperative whose structure description is given in the next section. These flows are also indicative of the flows of costs and revenues in the microsystem.

One way to discern the characteristics of a cooperative association is by comparing it with noncooperative firms. VanSickle (1980) presents a series of features that distinguish cooperatives from noncooperative corporations. These are summarized in Table 2.1. The role that a raw product plays in decision making by noncooperative firms and marketing cooperatives differs. In the former, the raw product is just an input in the vertical operation while for marketing or processing cooperatives the raw product is also the vehicle of return of the members' operations with the cooperative.

Another way to discern the characteristics of cooperative associations is by considering the principles that govern the interrelationships between a cooperative and its members. Abrahamsen (1976) states three principles: (1) service at cost by the cooperative, (2) member control and ownership, and (3) limited return on capital. These

principles make the conventional or neoclassical theory of the firm neither appropriate nor directly applicable to the study of cooperative associations.

Table 2.1. Differences Between Cooperative Associations and Noncooperative Corporations.

Feature	Cooperative	Noncooperative corporation
1. Benefits flow basis	Patronage	Investment
2. Ownership and control basis	Members	Investment
3. Return on capital	Limited	Open
4. Benefit form	As patron service users	As returns
5. Capital source	Stocks and deferred patronage refunds	Stocks
6. Stock price	Fixed	Market determined

Source: VanSickle, 1980, pp. 1-4.

Processing Cooperatives

The agricultural economics literature has not distinguished between processing cooperatives and pure marketing cooperatives. In addition to buy-sell and first-handler operations, processing cooperatives internalize the processing of the raw product supplied by the patrons by altering its form. This encompasses a greater dominion of a value-added system than pure marketing cooperatives. Since integration is costly and capital intensive, by extending the downstream boundaries these cooperatives involve higher capital investment, which increases the

likelihood of limited processing plant capacity and of inflexibility in membership, financial, marketing and organizational policies. In terms of Figure 2.1, this type of organization implies that $Y_{23} \neq Y_{13} \neq Y_{43}$.

The organizational implications associated with processing cooperatives point toward the need for a more detailed distinction from pure marketing cooperatives. To some extent, one can presume that these distinctive characteristics are linked to the nature of integration, to economic characteristics of the agricultural commodity involved and to the structure of markets both in the buying and in the final demand side of particular situations. Some distinguishing organizational characteristics of processing cooperatives are summarized in Table 2.2 and discussed below.

Table 2.2. Differences Between Pure Marketing and Processing Cooperatives[a].

Feature	Marketing cooperatives	Processing cooperatives
Degree of vertical integration[b]	+[c]	++
Alteration of raw product form	0	++
Perishability of raw product	+	++
Capital requirement	+	++
Restriction of membership likelihood	±	++
Members interdependence	+	++
Payment scheme complexity	++	+++

[a]These differences have not been directly observed, but derived in a hypothetical fashion in the text of the foregoing section.

[b]As measured by the share of the value-added system.

[c]The "+" sign indicates "High," "-" low, and "0" neutral.

Since processing cooperatives are a more integrated form of organization than pure marketing cooperatives, their boundaries encompass a greater dominion of the value added system of the agricultural and food industry. Marketing cooperatives, in a pure sense, engage in buy-sell operations for the members with little or no further service, other than centralizing the marketing of an agricultural commodity on behalf of their patrons. The grain cooperatives in the northern United States, for example, provide their members with the services of storage (elevators), and coordination and transfer of product to processors or wholesalers. Processing cooperatives advance to the next pricing point, by internalizing the processing of the raw product supplied by the patrons and marketing the finished commodity or commodities. However, most agricultural commodities require at least some transformation that cooperatives may undertake in the future.

Processing cooperatives are also more likely to handle a more perishable commodity than exclusively marketing cooperatives. The perishability of the product increases the propensity to forward integrate into processing to control or assure an outlet for the product, or to transform the commodity into a less perishable form.

Since integration is costly and capital intensive, processing cooperatives involve a higher amount of capital investment. This entails a greater commitment and possibly more inflexible membership policies. Restriction of membership due to a plant capacity constraint was found by Youde and Helmberger (1966). Too little volume may not allow the coverage of a high overhead cost. Too much volume, a result of the influx of new members, results in a purge of profitability of already existing members.

Since processing capacity is costly and therefore possibly limiting, the arrangements among members for sharing the plant capacity is more binding than in marketing cooperatives, especially when the commodity has a time-dependent use value and is highly perishable. Payment issues are more crucial in the case of processing cooperatives since adding the processing dimension has the implication of expanding the set of delivery attributes and variables that affect the value of the members' deliveries.

Cooperative Theory Development

The earlier studies of cooperation were of a socio-reformistic, descriptive and philosophical nature, leaving little or no room for criticism. More recently, cooperative theory has evolved in the framework of formal economic analysis, reorienting its treatment toward scientific interpretation. This section reviews the latter phase.

The pioneer study of Emelianoff (1948) portrays the cooperative as "an aggregate of economic units" with no decision making role. The cooperative, then, only coordinates the activities of the units which are directed by no central authority. Each unit retains its economic individuality and independence, which in turn leads to conflicting interests. He paved the road for posterior theory development, particularly by influencing Phillips.

Phillips (1953), who embraced Emilianoff's economic morphology, can be considered to be the first to present a formal and explicit cooperative model in a strict sense. He visualizes the cooperative as a multiplant operation in which the participating firms agree to function coordinately with respect to their joint activity. In this multiplant

environment, a cooperative member maximizes profits by equating the sum of the marginal cost in its own plant and the marginal cost of the cooperative plant, with the marginal revenue from the output sold by the cooperative.

Aresvik (1955), criticizing Phillips' analysis, proposes that equilibrium is based on the average cost and average revenue curves of the cooperative and not on the cooperative marginal curves as stated by Phillips (1953). He criticized Phillips for inferring about institutional arrangements exclusively from equilibrium conditions while overlooking normative premises. On this perplexing problem, he suggests that

> Making group decisions in the group of cooperating persons is, from a formal standpoint, exactly the same problem as making social choices based on individual ordering, which is intensively discussed in the literature of welfare economics. Today, I think, it is the consensus among the economists that it is impossible without value premises to make the step from individual orderings (preferences) to group orderings.
>
> (Aresvik, 1955, p. 143).

Trifon (1961) modified Phillips' equilibrium conditions, arguing that neither Phillips' nor Aresvik's conditions were appropriate. In his analysis, each member has to reconcile his own self-centered pursuit of profit with that of other members. He remarks that under the rule of patronage dividends, the inter-relationship of interests in a production or processing cooperative relative to marginal changes in total volume is as follows:

> Complementarity will prevail over phases of diminishing unit-costs. . . . Supplementarity will prevail over phases of constant unit-costs, and conflict will prevail over phases of rapidly rising unit-costs (resulting from exhaustion of inflexible capacity, especially under a severe resource restriction).
>
> (Trifon, 1961, p. 217)

Furthermore, Trifon's analysis shows that a member, by expanding his patronage, obtains only a fraction of the additional revenue and costs resulting from the adjustment by the cooperative, while his shares of initial total revenue and costs increase.

Kaarlehto (1956) initiated another line of thought by visualizing cooperation in the context of economic integration. His basic idea of cooperation relies on the integration of production and ordinary business activities. The relevant returns curves are then the average returns to each individual member and a joint (cooperative) average revenue curve. The joint average revenue is obtained as average returns of output less average marketing costs, and from this the members' marginal revenue product function is derived. To maximize profits members equate the joint marginal revenue product to their own marginal costs of production.

A very influential approach in the most recent vintage of cooperative models was developed by Helmberger and Hoos (1962). They conceived the cooperative in the framework of organization theory. In an organization, they argued, "the participants must adopt those decisional premises in choosing among alternative courses of action which will give rise to consciously coordinated activity" (p. 278). In their model, the cooperative is recognized as a single decision unit that strives to maximize the price of raw material to the members, or equivalently, to maximize the surplus resulting from "processing" members' (homogeneous) raw product and selling the finished commodity. The objective is inspired by the assumptions that physical patronage of each and all members is fixed and that members view the price received as fixed.

According to Helmberger and Hoos (1962) the objective of the cooperative is to obtain a maximum surplus of cooperative net savings corresponding to each level of members' output. This relationship depicts an average revenue product function, whose value is the per unit price paid to the members. Equilibrium is established where this curve intersects the members' supply function.

Hardie (1969) extended the Helmberger and Hoos model to a multiproduct case formulated as a linear program. He proposes to consider the shadow price of each product of the cooperative as the per unit return paid to the members so that each member receives the cooperative surplus earned by his products. This model allows for various types and grades of raw material and makes it the first to put the finger on the quality issue of the members' raw product.

Another extension of the Helmberger and Hoos model is the bargaining cooperative model presented by Ladd (1974). His model considers a multi-service cooperative of raw material producers which sells input to producers, provides a "free" service to producer members and nonmembers (unspecified though), and bargains with a processor for raw material price. His analysis shows that the cooperative objectives of maximization of quantity of raw material cooperatively marketed and the maximization of the raw material price paid to members, resulted not only in different optimality conditions but also that neither objective was equivalent to the total profit maximization conditions (marginal revenue equals marginal costs). These findings elicit the sensitivity of the cooperative operation to different objectives.

In the landmark work of Eschenburg (1971), the goal of the cooperative is the maximization of the sum of members' profits. He concludes

that a simultaneous equilibrium of all the members is generally unattainable since the level preferred by the members is not harmonious with the level preferred by management. Presaging the approach to cooperative theory and empirical work, he remarks:

> Since the results of cooperative activity depend upon the behavior of the participants, and since the behavior is largely, but not entirely determined by the organization structure (of the cooperative), it follows that the problem of optimal organization and operation can only be dealt with for specific organizations operating in particular environments. . . . The consequences for (cooperative) theory construction are that one can and must derive as many different theories as there are different (cooperative) organizational structures.
>
> (Eschenburg, 1971, pp. 84-85)[1]

Perhaps many issues can be best dealt with by specialized theories of cooperation as suggested above by Eschenburg (1971). On the same issue, Ladd (1982) stated

> The price we would have to pay for a general theory of cooperation is too high. We need a number of different special cooperative theories because no general theory can be small enough to be useful and manageable while being large enough to incorporate existing variations in cooperative objectives, environments, and problems.
>
> (Ladd, 1982, p. 2).

The above problem, indicated by Eschenburg (1971) and Ladd (1982), is not peculiar to cooperatives. However, the conventional theory of the firm is much more developed than cooperative theory to deal with specific situations and environments. Thus, there is a need to develop a theoretical framework for processing cooperatives and for individual and cooperative behavior under alternative arrangements among the members.

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[1]Vitaliano's (1977) version from the original in German.

Cooperative Arrangements

> It is reasonable to expect that the structure of the coop, the mechanism of control, the extent and nature of vertical integration, voting rules, and the standard operating procedures would be among the most important characteristics of cooperators related to their performance.
>
> (Shaffer, 1977, p. 168)

As the objective of the cooperative should be to benefit the members, different arrangements (instruments) may aim to achieve this objective but would generate different performance results in terms of the well-being of the members.

The preceding section has shown that a conflict-free or harmonious unconstrained cooperative operation is rarely, if ever, the case. Furthermore, the likelihood of conflict increases as the degree of downstream integration increases, making conflict issues of foremost importance to processing cooperatives. The conflicts in the joint operation of the cooperative, which introduce elements of dissociation, may be due to interdependence among the members. This may take the form of cross-externalities regarding the quality of raw product delivered and the use of restricted processing capacity. Since members are interdependent in the operation of the joint plant, agreements or arrangements are essential for workable guidelines of mutual share benefits and responsibilities.

In this study a marketing arrangement is referred to as a formal commitment between the cooperative and its members, in which the rights, duties and rules of operation for both the members and the cooperative are explicitly stated, with respect to the marketing of the members' commodities through the cooperative for services of processing and marketing. Along these lines, arrangements can be considered "instruments" of coordination of the members to achieve their objectives.

The principle of proportionality is the epitome of the organizational and financial policies established by the members. In theory, this principle provides equitable treatment of members. The operationalization of this principle is one of the most perplexing problems that cooperatives face. In this presentation arrangements are broken down into the areas of payment, financing, and processing.

Payment Arrangements

These arrangements refer to the computation of payments to members for their deliveries. Payments are made from the net savings of the cooperative operation. Alternatively, they refer to the allocation of net savings to the members for the contribution of their patronage. The first step in establishing these arrangements is the determination of the basis for patronage, i.e., what unit is to be used as the criterion to allocate payment (or charge in a supply cooperative) to the members. Some alternative methods are

1. The amount of service provided to the patron. This approach views the cooperative as a utility plant, where members are charged for the use of the services, and thus a "service" unit is the criterion of allocation when such service is subtracted from the savings.

2. Amount of raw material delivered. This provision ignores recognition of quality differentials. It is, however, an easy method to implement.

3. Use value basis. Each member is compensated by their contribution of their deliveries to the net savings of the cooperative.

The objective in selecting a payment scheme is to provide incentive and equity to the members who individually are attempting to maximize

profits. In establishing an adequate payment norm, members must first identify the raw product characteristics that affect the "actual" contribution of each member. Some of these characteristics are (1) volume delivered, (2) quality of the products delivered, (3) time of delivery, (4) producer location, and (5) services required from the cooperative. Ideally these factors should be taken into account for payment to the patrons. In one extreme, a truly equitable method of payment may prove disadvantageous to the members because of high implemention costs. On the other hand, a complete pooling in favor of a flat price for the raw product may distort the price signal sent to the members, and ultimately result in inefficiency in the cooperative operation.

Cooperatives resort to pooling, a process of averaging costs and returns, in establishing payments. The degree of pooling, then, refers to the extent of boundaries in characteristic space in which average costs and returns are applied, thus establishing a price for products contained in a given boundary. Commonly, grades are established in marketing cooperatives for payment purposes (Sosnick, 1963). Sosnick (1963) proposes four evaluation criteria for a pooling program:

1. The program should provide appropriate incentives to contract or expand the production of commodities and for grades or quality of a given commodity (adjustment in volume and quality);
2. The program should be equitable so that payment to the patron for his deliveries should not diverge from the net resale value of his deliveries;
3. The program should minimize the share of market risks borne by individual market lots; and

4. The program should minimize the costs of operating the pooling system.

Financial Arrangements

The ability of cooperatives to cope with challenges encountered when forward integrating, especially into the processing segments, is conditioned to the financial structure they possess. The spirit of proportionality dictates that capital should be supplied by the members proportionately to their volume of business. Some important financial structural parameters determined by arrangements are

1. The equity structure of the cooperative.

2. The pattern of retention of patron savings. Usually cooperatives pay an initial amount to patrons for deliveries and later refund the rest when the cooperative net saving has been determined. Different patterns of retention affect their members, especially if they have strong liquidity preference.

3. The determination of debt-equity of the cooperative, i.e., the degree of resorting to loans from outside sources (debt) to the capital provided by the member (equity).

The potential conflicts associated with capital share in proportion to patronage is that members may have different productivity of own capital, and thus, different reservation rates of return. As important as they are, the analysis of alternative financial arrangements and the search for sound financial strategies for cooperatives are set aside. This abstraction will allow more concentration on the issues surrounding the objectives of this study.

Processing Arrangements

These arrangements refer to the share of a fixed processing capacity that results from high capital cost of the cooperative plant. An additional factor that leads to processing arrangements is the specific pattern of use value over time, which is reflected in a pattern of perceived revenues by the members under a given payment scheme. Some arrangements associated with processing include

1. Temporal-related quotas. This arrangement would bind members to send deliveries during any period of the processing season, in such a way that deliveries of all members are scheduled proportionally across members and over time.

2. Production quotas. Minimum quantity requirements may be necessary to protect the cooperative from high operating costs due to inadequate volume.

3. Production ceilings. A symmetric argument holds for the imposition of upper bounds in the deliveries of raw material to the members, to protect the members of autopenalizing when operating beyond overall optimal cooperative capacity. To the knowledge of the author, these arrangements have not been explored. Such arrangements, however, would appear to be controversial.

Control and Cooperative Objective

The settlement of arrangements are conditioned by the manner in which control and decision making are shared by the members. Abrahamsen (1976) recognizes two types of voting policies used by cooperatives: equal voting (one man-one vote) and patronage voting (voting power

relative to patronage). As most cooperatives have been identified with the first voting system, traditional ideas of what constitutes equitable participation may need to be revised when cooperatives increase in complexity of operation and when member patronage varies greatly.

The internal power structure of the cooperative can be characterized by a pyramid of control composed of three levels: the members, the board of directors, and the management team. The decision making dominance of one level over another affects the type of arrangements generated to achieve the objectives of the dominant element. The causality paradigm appears to indicate that, in general, decision making flows from the members toward management, ending in a bottle-neck in discretionary decision power.

As suggested by Aresvik (1955), decisions in cooperatives appear to be analogous to social choices. Economists, however, can only indicate a partial ordering of decision, without normative premises, with the Pareto criterion. Each member is visualized as a rational individual that would join the cooperative to increase his utility, and any voting side chosen is an attempt to enhance his satisfaction. The cooperative then is viewed as an institution to increase utility or well-being of the members by increasing profits, decreasing (price, quantity, quality) risks, and possibly providing some public-type goods. Given that profit and risk are the primary argument of a member's utility function, the member in isolation would strive to maximize a weighted average of profits and (negative weight for risk aversion) risks. An oversimplification of members' behavior is that they attempt to maximize profits. As all members try to do so, conflicts emerge which are settled according to the power of members, directors or management. The outcomes from

the exercising of power in the cooperative groups are arrangements to delineate the rules of marketing the members' product.

Earlier work has not recognized the role of decision making by the cooperative (e.g., Emelianoff, 1948; Phillips, 1953), and thus contain no explicit cooperative objective. More recent work, however, has stressed an active decision making role, while possessing a single objective. The sensitivity of the cooperative outcome to the assumed objectives was illustrated by Ladd (1974), where he shows that an efficient quantity maximizer differs from an efficient price maximizer (as in Helmberger and Hoos), and both differ from profit maximizers. Plausible cooperative objectives are

1. Minimization of costs. This objective appears to be plausible only if the cooperative had fixed or zero (supply cooperatives) revenue, which is equivalent to maximizing profits, or better said, it would be a subcase of the profit maximization objective.

2. Maximization of cooperative surplus or price. This objective, stated by Helmberger and Hoos (1962), seems plausible when patronage is fixed (e.g., the very short run). This is indeed a subcase of the total profit maximization case, where the level of output of the members (and thus their production costs) is fixed. Then the only viable way to maximize members' profits is to maximize net cooperative surplus.

3. Maximization of total members' profits. In the Helmberger and Hoos framework, this would imply at least that the volume of deliveries of the members is not fixed, and thus there is flexibility to adjust to the point of maximum profits. Ladd (1982) and Eschenburg (1971) have supported this objective on the grounds that it better resembles the individual objective of maximizing profits. Indeed, why should the

cooperative maximize its net surplus instead of maximizing the sum of "members' surplus" which is total profits?

The use of a single objective in cooperative models is a gross oversimplification of the plurality of objectives a cooperative considers. An illustration of this is provided by Jacobson (1972) who found four primary objectives that describe the service role of milk cooperatives:

1. To guarantee their producers a market,
2. To bargain for the best possible terms,
3. To assemble and market the milk as efficiently as possible, and
4. To help achieve higher quality levels in incoming milk markets.

The last three objectives aim directly to increase the total profits of the members. At this crossroad a controversial question is: can the cooperative achieve the total profits maximum through alternative arrangements? These issues are the ones that this study attempts to explore. The extent that alternative arrangements can improve the performance of cooperatives depends upon the behavior of the members under those arrangements. Such behavior, along with its underlying rationale, is explored in the following chapter.

CHAPTER III

A CONCEPTUAL FRAMEWORK FOR COOPERATIVE BEHAVIOR AND PERFORMANCE

Perhaps the most basic behavioral postulate of economics is that man is egoistic, rational and a utility maximizer. Even though the basic behavioral force of increasing well-being is what induces a group of farmers to "cooperate" by forming a cooperative association, individually they are likely to engage in independent noncooperative behavior. The resulting behavior, from a conceptual standpoint, is analogous to the prisoner's dilemma.[1] Such behavior results from a member's dilemma where he has incentive to "free ride" (and thus capture gains when other members are behaving for the cooperative welfare) or to "protect" himself when other members are attempting to "free ride."

The purpose of this chapter is to provide a conceptual framework to investigate the behavior of processing cooperative members and to assess the welfare implications of alternative coordination arrangements among the members that may induce compliance to attain cooperative coordinated equilibriums. The model structure and analysis incorporate coordination mechanisms, membership adjustments and open market purchases strategies. The model allows analysis of a broader class of group behavior problems, in particular free riding and the cooperative analogy of the prisoner's dilemma.

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[1]Luce and Raifa (1957) present a discussion of the classical prisoner's dilemma game.

A Mathematical Model of Processing Cooperatives

Consider a processing cooperative which purchases a homogeneous raw product, y, and transforms it into a finished product Z. The cooperative sells Z in a competitive market at price P_z. The net revenue of the cooperative, called cooperative surplus (CS), is

$$CS = P_z Z - C(Z,P) - FCC, \tag{3.1}$$

where C(Z,P) is the variable cost of transforming y into Z, P is a vector whose elements are the prices of other inputs, and FCC is the fixed cost of the cooperative.[2]

Let y_i denote the delivery of raw product by member i. Assume there are m growers and the membership is closed. Then the total raw product to be processed by the cooperative is[3]

$$Y = \sum_{i=1}^{m} y_i \ . \tag{3.2}$$

Since the cooperative is organized solely for the benefit of its members, it must distribute all the cooperative surplus (CS) back to the members. Thus,

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[2]At this juncture, we assume that the cooperative is technically efficient in the sense that it produces a given output at minimum cost, or by duality it maximizes output for a given expenditure level. For the remainder of the analysis it is assumed that the fixed cost of the cooperative is the same for the time spans implied. This is not an innocuous assumption when one considers the relatively extensive capital longevity associated with processing assets. A complementary analysis with fixed and variable cooperative plant size in the long run is presented in Appendix A.

[3]So far we are assuming that the cooperative does not buy outside in the open market. This assumption is relaxed later.

$$\sum_i PAY_i = CS, \tag{3.3}$$

where PAY_i denotes the payment to grower i for the delivery of y_i.

Assume that the members are homogeneous (identical), then $y_i = y_j$, for all i and j. For notational convenience, let $y_i = y$, so that (3.2) becomes my = Y. Under the assumption of member homogeneity $PAY_i = PAY_j$ for all i and j, and letting $PAY_i = PAY$, (3.3) becomes

$$mPAY = CS \tag{3.4}$$

A relationship exists between y, individual production, and PAY, individual payment. Define P_y to be the "price" per unit of member output,[4] the average net revenue product (ANR) of the cooperative, then

$$PAY = P_y y \tag{3.5}$$

and

$$P_y = \frac{CS}{my} . \tag{3.6}$$

Cooperative Behavior and Optimal Volume

Myopic and Coordinated Behavior

In the short run, the member's production function and the corresponding cost-function are constrained by the existence of fixed inputs which are linearly weighted by their prices to constitute the fixed cost of producing the raw material in the time span considered.

This input fixity may not only arise from asset fixity in the short run (e.g. land, machinery and multi-period crops) but also from

[4]The price definition given in (3.6) is basically the same as the one given by Helmberger and Hoos (1962). The differences are that they treated members' total raw product as fixed and they did not distinguish the raw product of each member.

contractual obligations or other business arrangements. Given some fixed inputs, a typical cooperative member strives to maximize net returns,[5] that is to maximize

$$\pi = P_y y - c(y,W) - FC, \tag{3.7}$$

where $c(y,W)$ is the variable cost of producing y with variable inputs whose prices are denoted by a vector W, FC is the fixed costs of the grower and P_y is defined as above.

Total profits of the members are

$$\pi^c = m\pi = P_y my - m\,c(y,W) - mFC = m(P_y y - c(Y,W) - FC) \tag{3.8}$$

which is simply m times each member's maximand. Thus, the value of y which maximizes individual maximum profits is the same value which maximizes total profits. The first order condition for profit maximization is

$$\frac{\partial \pi}{\partial y} = P_y + \frac{\partial P_y}{\partial y} y - \frac{\partial c}{\partial y} = 0. \tag{3.9}$$

Equation (3.9) says that the individual grower should equate marginal revenue and marginal costs. Two subcases arrive with respect to the member behavior. These cases are myopic and coordinated cooperative, depending on how the members regard $\partial P_y/\partial y$, the slope of the average net revenue function.

In the myopic case members are driven by strategic individual rationality and thus behave solely as quantity adjusters, regarding P_y

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[5]A single objective of profit maximization is assumed. However, the member may receive nonpecuniary benefits from its cooperative membership which increase his utility but not his net returns.

as invariant, i.e., as if $\partial P_y/\partial y$ is zero. The likelihood of this case is increasingly plausible as the members are "atomized" with respect to the scale of the cooperative since the price a member receives is largely independent of his delivery. This suggests the potential for myopia as individual members' share of the operation decreases. In this case, set $\partial P_y/\partial y$ equal to zero and solve (3.9) for y to obtain a member's supply function. The aggregation of these functions is the members' supply function. In inverse form[6]

$$P_y^s = P_y(my, W). \tag{3.10}$$

Analogous to the result of Helmberger and Hoos (1962), cooperative equilibrium is established where (3.10) intersects (3.6).

Consider the case of a coordinated cooperative in which the members behave in a collectively rational way. If the members recognize their interdependence and react in a coordinated way such that they fully recognize the impact of their output level on the price they receive, each would attain a higher level of profits. Differentiating (3.6) with respect to y gives

$$\frac{\partial P_y}{\partial y} = \frac{(\partial CS/\partial y)y - CS}{my^2}. \tag{3.11}$$

Substituting (3.11) into (3.9) yields

$$\frac{\partial \pi^c}{\partial y} = P_y + \left[\frac{(\partial CS/\partial y)y - CS}{my^2} \right] y - \frac{\partial c}{\partial y} = 0. \tag{3.12}$$

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[6]It is assumed that aggregate supply embodies a monotonic function; thus, it can be inverted while retaining a one-to-one mapping of quantity and price.

Using (3.6) gives

$$\frac{CS}{my} + \frac{1}{m}\frac{\partial CS}{\partial y} - \frac{CS}{my} - \frac{\partial c}{\partial y} = 0. \qquad (3.13)$$

Thus

$$\frac{\partial CS}{\partial y} = \frac{\partial c}{\partial y} m. \qquad (3.14)$$

Equation (3.14) implies that for maximum total profits the members should produce at the intersection of their supply curve ($\frac{\partial c}{\partial y} m$) and the cooperative marginal surplus or marginal net revenue curve (MNR). This represents a coordinated equilibrium. Equation (3.14) also implies that for a coordinated solution the marginal cost of producing y incurred by each member ($\partial c/\partial y$) must equal their share of the marginal cooperative surplus ($\partial CS/\partial y$) $\frac{1}{m}$.

Substituting (3.14) into (3.9) for $\partial c/\partial y$, the marginal net revenue for a grower is

$$\frac{1}{m}\frac{\partial CS}{\partial y} = y\frac{\partial P_y}{\partial y} + P_y. \qquad (3.15)$$

Thus, if members regard P_y as beyond control, the individual will act as if marginal revenue is P_y. To determine the sign and magnitude of $\partial P_y/\partial y$, manipulate equation (3.15) to obtain

$$\frac{\partial P_y}{\partial y} = 1/y\left(\frac{\partial CS}{\partial y}\frac{1}{m} - P_y\right). \qquad (3.16)$$

If P_y (ANR) exceeds the member share of the marginal revenue (ANR > MNR/m), then $\partial P_y/\partial y < 0$ and myopia would have implicit cost. Thus, there would be pecuniary advantages of increasing the sophistication of the cooperative toward the coordinated case.

Differentiating equation (3.1) gives

$$\frac{\partial CS}{\partial y} = P_Z \frac{\partial Z}{\partial y} - \frac{\partial C}{\partial Z}\frac{\partial Z}{\partial y} . \tag{3.17}$$

Substituting (3.17) into (3.14) and rearranging gives

$$(P_z - \frac{\partial C}{\partial Z}) \frac{\partial Z}{\partial y} = m \frac{\partial c}{\partial y} . \tag{3.18}$$

Similar to equation (3.14), equation (3.18) says that for a coordinated solution y is adjusted until the aggregate supply of the members ($m \frac{\partial c}{\partial y}$) equal the marginal net revenue of the cooperative (MNR) on the left hand side.

In a situation of myopic equilibrium and $\partial P_y/\partial y$ negative, then it is advantageous for members to jointly reduce deliveries to the point where the raw material price increase plus the grower's cost reduction balance the foregone revenues associated with the lower volume of deliveries; that is, to move to a coordinated equilibrium. If positive, then the cooperative may increase its membership ($m^* > m$), buy in the open market or encourage members to increase their deliveries.

In Figure 3.1, myopic and coordinated equilibrium are depicted. Myopic equilibrium occurs at point e where the members' supply function (S) intersects the average net revenue function (ANR) of the cooperative. Coordinated equilibrium occurs at point c, where the members' supply function intersects the marginal net revenue function (MNR) of the cooperative. The myopic cooperative produces my^e and receives P_y^e (point e) while the coordinated cooperative produces my^* and receives P_y^* (point c). Note that at point e $\partial P_y/\partial y < 0$, and point c is Pareto superior in the sense that individual and total profits are greater than under noncooperative myopic behavior at point e. From the concavity

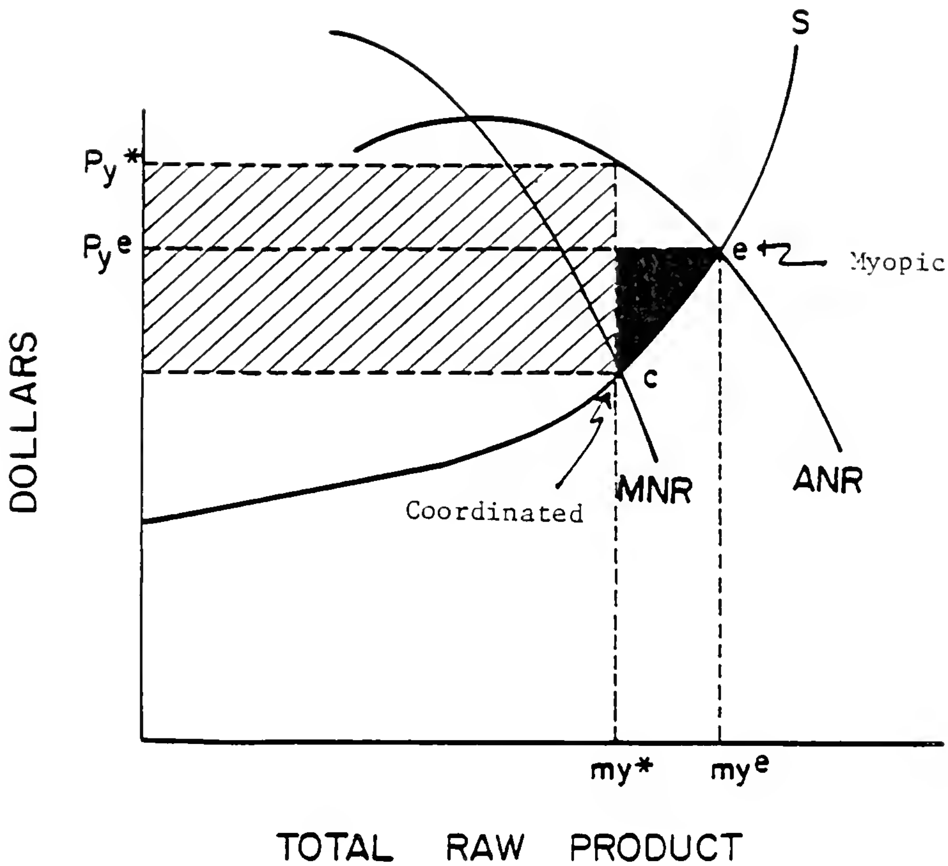

Figure 3.1. Myopic and Coordinated Equilibria.

condition for profit maximization at point c, total profits decrease as the cooperative operates to the left of c. In this fashion one finds a point where cooperative profits are identical to the myopic cooperative profits but the delivery volume is even smaller than in the coordinate case.

Rationale for Myopia

A rationale for myopia can be derived in terms of the above results. Under the prevailing arrangements, a member has an incentive to increase his individual delivery, for example, from a coordinated cooperative position. To illustrate the last point, combine equations (3.14) and (3.15) to obtain the following expression of a coordinated equilibrium

$$\frac{\partial c}{\partial y} = y\,\frac{\partial P_y}{\partial y} + P_y.$$

At a coordinated solution, such as the one depicted at point c in Figure 3.1, $\partial P_y/\partial y < 0$. Thus, at that point, a myopic member perceives $\partial P_y/\partial y = 0$ and therefore perceives $\partial c/\partial y < P_y$. If he behaves individualistically then he would increase his deliveries of raw material. This incentive arises from the fact that marginal return to a member in isolation is greater than its marginal cost of producing y. If all members react in the same way, they would gradually move from point a toward point e. P_y would simultaneously be decreasing up to where further increases in deliveries are no longer desired, at point e, in myopic equilibrium. This equilibrium position would be stable as long as members retain myopia, or as long as no arrangements are tailored to induce them to produce at point c.

Such behavior results in a member's dilemma where he has incentive to "free ride" (and thus capture gains when other members are adhering to coordinated cooperative behavior) or to "protect" himself when other members attempt to "free ride." The group behavior result, from a conceptual standpoint, is the cooperative analogue of the prisoner's dilemma. The pursuit of self-interest (individual rationality) produces an outcome that is collectively irrational. Point e in Figure 3.1 (myopic equilibrium) coincides with the cooperative equilibrium of Helmberger and Hoos (1962). The foregoing analysis has identified the source of "myopia" and a coordinated equilibrium.

One can notice the similarity of this analysis with that of cartels, although in a closed processing cooperative unnoticed cheating is less likely because the cooperative management monitors and knows the activities of each member.

Cooperative Surplus and Price Sensitivity

Rearrange equation (3.11) to yield

$$\frac{\partial P_y}{\partial y} = \frac{1}{my} \left[\frac{\partial CS}{\partial y} - \frac{CS}{y} \right].$$

Use the payment definition given in equation (3.6) to multiply the right-hand side by $P_y/(CS/my)$ (which equals one). Then multiply and divide by y and eliminate my from the resultant expression to obtain

$$\frac{\partial P_y}{\partial y} = \frac{P_y}{CS} \frac{y}{y} \left[\frac{\partial CS}{\partial y} - \frac{CS}{y} \right]. \tag{3.19}$$

After multiplying both sides of (3.19) by y/P_y and manipulating the result, one obtains

$$\eta_{P_y,y} = \eta_{CS,y} - 1 \tag{3.20}$$

where $\eta_{P_y,y} = \frac{\partial P_y}{\partial y} \frac{y}{P_y}$ is the elasticity of raw material price with respect to members' deliveries and $\eta_{CS,y} = \frac{\partial CS}{\partial y} \frac{y}{CS}$ is the elasticity of the cooperative surplus with respect to members' deliveries.

Equation (3.20) depicts the relationship between the sensitivity of cooperative surplus and member price to changes in deliveries. If $\eta_{CS,y}$ equals one, then $\eta_{P_y,y}$ equals zero and myopic equilibrium and coordinated equilibrium coincide. The more inelastic cooperative surplus is to raw material deliveries ($\eta_{CS,y}$ close to zero), the greater the impact of coordination and the greater the amount of raw material reduction required to achieve the state of maximum total profits. This follows since small $\eta_{CS,y}$ implies cooperative surplus changes little as total deliveries are reduced; however, the value of P_y increases, since P_y = CS/my.

The above statement implies that with higher capital investment of the cooperative (which generates higher cooperative fixed outlays), the more crucial it becomes for the cooperative to assure adequate supplies of raw material for its survival and to return an adequate payment to its members. Thus, if fixed costs dominate, the price received by members is more sensitive.

A vertically integrated firm facing the same cost structure as the foregoing cooperative would produce at the coordinated output (point c, Figure 3.1). However, as $\eta_{CS,y}$ becomes nearly one the performance difference between a myopic cooperative and a noncooperative vertically integrated firm vanishes.

Arrangements to Ensure Coordinated Behavior

Three approaches are envisioned as potential instruments to ensure a coordinated equilibrium:

1. Given m members, impose a quota of $y=y^*$ to each member. In this case the members supply curve becomes vertical at an aggregate supply level of my^*. The cooperative will only accept deliveries consistent with the optimal capacity use.[7] An equivalent but analogous instrument is the institution of processing rights to be sold by the cooperative. In the context of our model, the coordinated state would be achieved if the cooperative sells each member the right to process y^*. This arrangement is a cooperative-mapping of coercion as the only way to ensure that the preferred outcome is obtained, as suggested by Hobbes (1909).

2. Educate the members as to the effect of $\partial P_y/\partial y$. However, if such optimal volume is not enforced, a conscious-raising program seems rather utopic since members will always have an incentive to cheat. They would free ride at the expense of other members that are cooperating in attaining the coordinated solution, and subsequent retaliation would establish myopic equilibrium.

3. Impose an internal tax on deliveries exceeding y^*, a penalty at least equal to the difference of P_y^* received at optimal capacity use and the grower's marginal cost of producing y (point c, Figure 3.1). In this way no individual marginal gains would occur beyond y^*, and incentives to cheat would be eliminated.[8]

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[7]The use of a point quota is only for pedagogic purposes. It is, of course, more realistic to impose upper and lower quotas (interval quotas).

[8]The problem here is similar to the problems of maximizing cartel profits; however, here the delivery level can be directly observable, and thus penalized.

Benefits from Coordination

Consider the benefits of the coordinated equilibrium as compared to the myopic equilibrium. Total profits are cooperative surplus less members' total costs. Cooperative surplus equals the members' gross revenues. Following Just et al. (1982) in measuring producers' welfare changes quasi-rents are given by profits plus the members' fixed costs. At myopic equilibrium cooperative surplus (gross revenues to the members) is given by $P_y^e m y^e$ in Figure 3.1. The area below the supply curve represents the total variable costs of the growers. Thus the area above the supply curve and below the price measures the total quasi-rents that accrue to the members. The change in total profits or producers' quasi-rents from moving into a coordinated equilibrium is given by the cross-hatched area less the solid shaded area in Figure 3.1.

Underutilized Cooperative Plant

This situation arises when myopic equilibrium occurs in the rising region of the ANR function, and thus there are yet size economies of the cooperative processing plant to be exploited (to the left of point e in Figure 3.2).

One can reasonably postulate that membership size (m) is sticky downward in the short run, i.e., membership expansion is more likely to occur than membership contraction. Note that coordinated equilibrium at point c, Figure 3.2, with membership m_1 is not attainable since the cost of producing such output exceeds the revenues received by the members. A noncooperative firm buying solely from m_1 independent growers and having the same cost structure as the foregoing cooperative, cannot stay

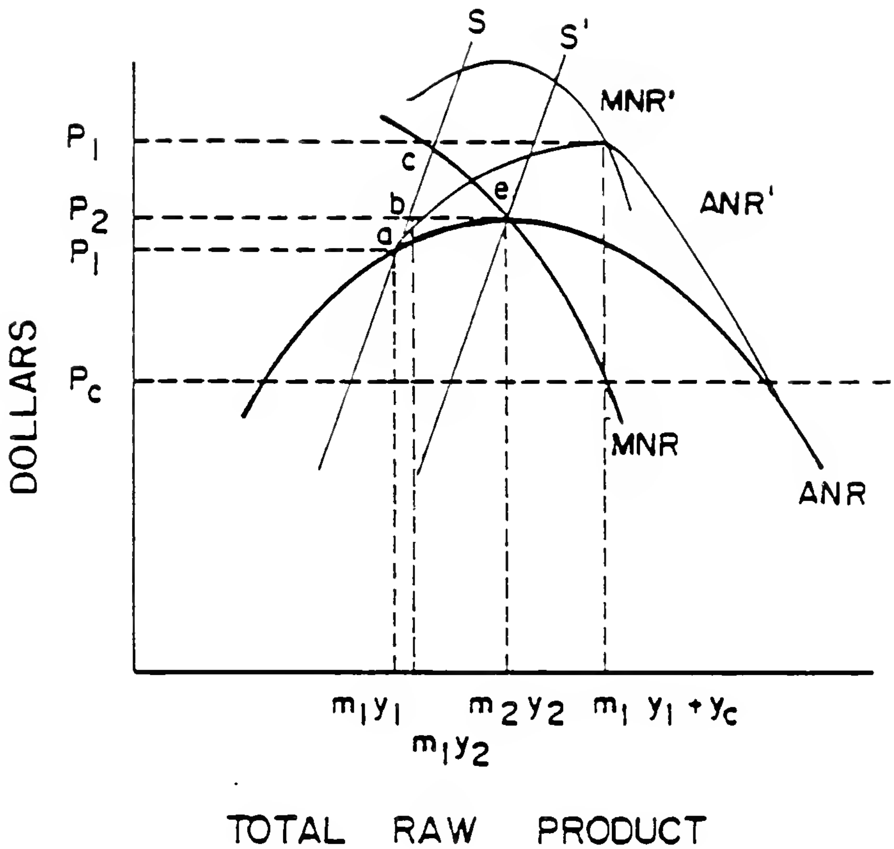

Figure 3.2. Alternative Membership and Open Market Purchase Policies for an Underutilized Cooperative Plant.

in business at point c. This provides a rationale for the formation of cooperatives to protect markets where there is lack of profitability in the processing stage. The cooperative subsists at myopic equilibrium with m_1 members, each producing y_1 and receiving price P_1.

If the cooperative is operating below optimal capacity, two choices may be available to allow cooperative volume expansion: increasing membership size, and buying raw material in the open market. These situations are compared in Figure 3.2.

An influx of $m_2 - m_1$ new members shifts the raw product supply from S to S' and increases the price received by already existing members (to P_2), and therefore the amount supplied by each member (to y_2). With membership adjustment only, this corresponds to the optimal membership--profits of the m_1 already existing members are increased by abP_1P_2.[9]

Holding each member output constant ($y = \bar{y}$), and differentiating (3.7) gives

$$\frac{\partial \pi}{\partial m} = \frac{\partial P_y}{\partial m} \bar{y} . \tag{3.21}$$

Further, differentiating (3.7) and using (3.6),

$$\frac{\partial \pi}{\partial m} = \left(\frac{\partial CS}{\partial m} - \frac{CS}{m} \right) \frac{1}{m} . \tag{3.22}$$

Setting (3.22) equal to zero we find that with each member providing $y=\bar{y}$, optimal membership level is where the marginal cooperative surplus contribution of the last member equals the average surplus that accrue to all members ($CS/m = \partial CS/\partial m$).

[9]Optimal membership size here is referred to as the one that maximizes per capita profits, that is, the value of m that an individual cooperative member would prefer, assuming no altruism and that m is endogenous.

If the open market price of the raw product is lower than that received by the members at equilibrium, it is more advantageous for the cooperative to buy in the open market rather than expanding membership. To illustrate, assume that in the open market raw product may be acquired at price P_c. If the cooperative buys in the open market it would not only capitalize on scale economies of the cooperative processing plant, but also on marginal value of raw material bought outside which exceeds its marginal cost of acquisition (P_c). Thus, the relevant average net revenue curve is above ANR because of the exploitation of nonmembers' raw material from generating surplus that they do not pay back to the sellers (ANR' in Figure 3.2). Members supply m_1y_1, and the cooperative would buy y_c in the market to receive price P_1^*, while sticking to membership m_1. Profits to the m_1 members would be higher than when they expand membership since their marginal cost given by S is higher than their marginal cost of buying in the open market (P_c). The potential instability of P_c, however, may invalidate these conclusions. In the case of fluctuating P_c, it may be preferable to increase membership to assure adequate raw material supplies.

Payment for Quality

In the foregoing discussion, the complications that may arise if variations in raw product quality are taken into consideration have been disregarded. The volume (quantity) is but one dimension of the raw product delivered by the members. Many problems, however, are derived from the heterogeneous characteristics of the commodity involved where the homogeneous product case is neither convenient nor appropriate. Probably the most important problem related to product characteristics

is the appropriate payment or compensation to the grower for the objectively measurable characteristics of his product.

The final commodity produced by the cooperative is assumed to be homogeneous (Z), so that we abstract from the effects of quality variation on the final demand side. This allows quality to be determined solely by the decisions of the cooperative members, affecting the cost or supply side of the operation where the payment of the growers is generated.[10] Let the raw product possess a set of characteristics, and let A be a 1 by k vector of continuous and unambiguously measurable characteristics $A=[a_1, \ldots, a_k]$, where each characteristic is indexed by i. The vector A contains only the relevant characteristics of the raw product; that is, the ones that affect cooperative surplus. Assume that the level of characteristics can be influenced by the members and that y is the amount of raw material produced by the members. Let the growers' cost function be given by $c = c(y, A; W)$, where W is the vector of factor prices and the marginal costs of the arguments in c are positive and increasing.

Assume that the characteristics are such that the higher a_i, the more the contribution to cooperative surplus (characteristics measured as "goods"). Normally the level of each characteristic would have bounds that define the technically feasible set or institutional regulations. Define an arbitrary payment function that the cooperative

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[10] Implied in the analysis that follows is that the raw product identity, in terms of the relevant characteristics, is kept throughout its processing. This excludes the case where the raw product undergoes a blending process in which the product identity is lost since the nature of the finished product depends also on the choice of characteristics of other materials that are mixed with the members' raw product.

utilizes to distribute the cooperative surplus back to the members. The payment per unit of y is defined to be $P = P(\lambda A)$, where λ is a diagonal matrix whose diagonal elements are the pooling parameters that define the payment scheme. If characteristic a_i is pooled, then λ_i is zero, if not $\lambda_i = 1$.

Below, the behavior of the members is analyzed under two payment schemes: fully accurate pricing, when no characteristics are pooled, and pooling or imperfect pricing, when at least one characteristic is pooled.[11] The effect of pooling schemes on the location of the ANR function can be translated into allocative efficiency issues since it distorts the signal sent to the members, and under individualistic behavior it modifies the maximand of individuals. It must be kept in mind that under the assumption of member homogeneity, raw product supply (y) and characteristics will be the same across members; however total raw product and characteristics levels may be different across payment systems.

Fully Accurate Pricing

If payment is not distorted in the sense that it fully accounts for the contributed cooperative surplus, no characteristics are pooled. This case implies that $\lambda = I_k$, a k-dimensional identity matrix. Thus, a typical member maximizes

$$\pi = P(A)y - c(y, A; W) - FC. \tag{3.23}$$

[11] In this model the term "pooling of characteristics" is intended to denote the pooling of cooperative costs and revenues associated with the characteristics.

Assuming an interior solution, the first order conditions are given by[12]

$$\frac{\partial \pi}{\partial y} = P + \frac{\partial P}{\partial y} y - \frac{\partial c}{\partial y} = 0 \tag{3.24}$$

$$\frac{\partial \pi}{\partial a_i} = \frac{\partial P}{\partial a_i} y - \frac{\partial c}{\partial a_i} = 0. \qquad i = 1, \ldots k \tag{3.25}$$

Equation (3.24) states that maximum profits are reached when the physical quantity of raw material (y) is set where its marginal revenue equals the marginal cost of producing it incurred by the members. Equation (3.25) indicates that it is also necessary that the level of characteristics be set where their marginal revenue equals the marginal cost of producing them incurred by the members. Even though under fully accurate pricing members are coordinated with respect to characteristics of the raw product, myopic behavior with respect to the volume of deliveries (y) is likely if there are no discriminatory pricing or quota schemes to control the supply of raw material.

Pooling

With imperfect pricing accuracy $\lambda - I_k$ is a negative semi-definite matrix and at least one λ_i equals zero, implying some pooling. Further, assume P is homogeneous of degree one in λ_i so that $\partial P/\partial(\lambda a_i) = \lambda_i(\partial P/\partial a_i)$. When some characteristics are pooled, an individual has the incentive to set it at minimum cost level. Let a_i^o be the lower limit on

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[12]In what follows it is assumed that the production technology is characterized by nonjointness in characteristics and quantity of the raw product. This implies that $\partial y/\partial a_i = 0$ and $\partial a_i/\partial a_j = 0$ $(i \neq j)$. This assumption is questionable if the production technology is such that the choice of one characteristic is not independent of other characteristics or of the amount of raw material. For the sake of simplicity, however, nonjointness has been assumed in the production of raw material.

the i^{th} characteristic whose imputed value is given by β_i. Then, a typical member strives to maximize

$$\pi = P(\lambda A)y - c(y, A; W) - FC + \sum_i \beta_i(a_i^o - a_i) \tag{3.26}$$

The Kuhn-Tucker conditions are

$$\frac{\partial \pi}{\partial y} = P + \frac{\partial P}{\partial y} y - \frac{\partial c}{\partial y} \leq 0; \qquad \frac{\partial \pi}{\partial y} y = 0 \tag{3.27}$$

$$\frac{\partial \pi}{\partial a_i} = \lambda_i \frac{\partial P}{\partial a_i} y - \frac{\partial c}{\partial a_i} - \beta_i \leq 0; \qquad \frac{\partial \pi}{\partial a_i} a_i = 0 \tag{3.28}$$

$$\frac{\partial \pi}{\partial \beta_i} = a_i^o - a_i \leq 0; \qquad \frac{\partial \pi}{\partial \beta_i} \beta_i = 0 \tag{3.29}$$

Assume an interior solution for y and for nonpooled characteristics. If the i^{th} characteristic is pooled then $\lambda_i = 0$ and the myopic member produces at $a_i = a_i^o$ at minimum cost level since there is no direct perceived pay-off of producing higher levels of a_i. The above system of equations is the heterogeneous raw product analogy of equation (3.9).

Assume an interior solution for y and for nonpooled characteristics. β_i is the imputed value of $a_i = a_i^o$; that is, $\beta_i = \partial\pi/\partial a_i^o$. Thus, β_i is the change in π that results when a_i^o is increased and therefore, for an individual member, it is negative. Following the argument used earlier, one can derive the expressions below

$$\frac{1}{m} \frac{\partial CS}{\partial y} = P_y + y \frac{\partial P_y}{\partial y}$$

$$\frac{1}{m} \frac{\partial CS}{\partial a_i} = \lambda_i \frac{\partial P}{\partial a_i} y.$$

$\lambda_i = 0$ says that the grower perceives $\partial P/\partial a_i = 0$, i.e., he does not perceive any impact of a change of a_i on the price he receives. If $\lambda_i = 0$, (3.28) becomes $-\frac{\partial C}{\partial a_i} - \beta_i = 0$ (if $a_i > 0$), which implies $\partial C/\partial a_i = -\beta_i$. With pooling and lower limits on characteristics, the marginal cost of producing a_i is equated to its imputed value. If minimum levels of a_i were set such that $\overset{o}{a_i} = \overset{*}{a_i}$ of a coordinated solution, a coordinated solution can be attained solely with the imposition of appropriate minimum levels of acceptable characteristics.

Equilibria Location

With k characteristics, the location of the average revenue function of the cooperative and the location of the members' supply function is in a k+1 dimensional euclidean space. Take the ratio of the marginal conditions for two characteristics a_i and a_j $(i \neq j)$.
From equation (3.28)[13]

$$\frac{\lambda_i \frac{\partial P}{\partial a_i}}{\lambda_j \frac{\partial P}{\partial a_j}} > \text{ or } < \frac{\partial c/\partial a_i + \beta_i}{\partial c/\partial a_j + \beta_j} \tag{3.30}$$

Hold the assumption of unique interior solution for nonpooled characteristics. If no pooling occurs, then $\lambda_i = 1$ and $\beta_i = 0$ $(i=1, \ldots, k)$. Then the left-hand side of (3.30) can be derived from the payment function and the right-hand side from an isocost function. Optimality requires that the slope of the payment function (per capita

[13]The inequality signs in (3.30) stand for the cases where pooling occurs. If a_i is pooled $(\lambda_i = 0)$ then the left-hand side of (3.30) is zero and therefore smaller than the right-hand side. If a_j is pooled $(\lambda_j = 0)$ then the left-hand side is infinite and therefore greater than the right-hand side.

cooperative surplus) be tangent to the slope of the grower's cost function. For maximum net returns to occur, the increase in payment per marginal increase in cost must be equal among all characteristics. If a_i is pooled and a_j is not, then $\lambda_i = 0$ and β_i is positive while $\lambda_j = 1$ and β_j is zero. For a nonpooled a_i, a myopic member perceives a flat marginal revenue function in a_i's dimension, however it is not flat if a_i affects cooperative surplus.

To analyze further the quality and quantity locations of equilibrium, let a single variable characteristic be denoted as "a." An increase in "a" implies an upward shift of the ANR function ("a" measured as a "good") and a leftward shift of the members' supply function (since the marginal grower's cost is a positive and increasing function of its arguments). With the amount of raw material held constant ($y = y^0$) members will supply higher quality only at a higher per unit price of y. Alternatively, they will supply more y only if quality is inferior for a given price of y. When quality is improved, say from a stimulus to produce higher quality, supply shifts to the left while average revenue shifts upward. Whether the members produce more or less quantity of raw product after producing higher quality is indeterminate. The outcome depends upon the sensitivity of the average net revenue function (or cooperative surplus) to quality relative to the sensitivity of the supply function of the members. Figure 3.3 illustrates two cases of the amount of raw product responsiveness to increases in characteristic "a." For a supply function that is relatively insensitive, equilibrium occurs at point 2 and the amount of raw product increases. For a very sensitive supply function equilibrium occurs at point 3 and the amount of raw product decreases. One result

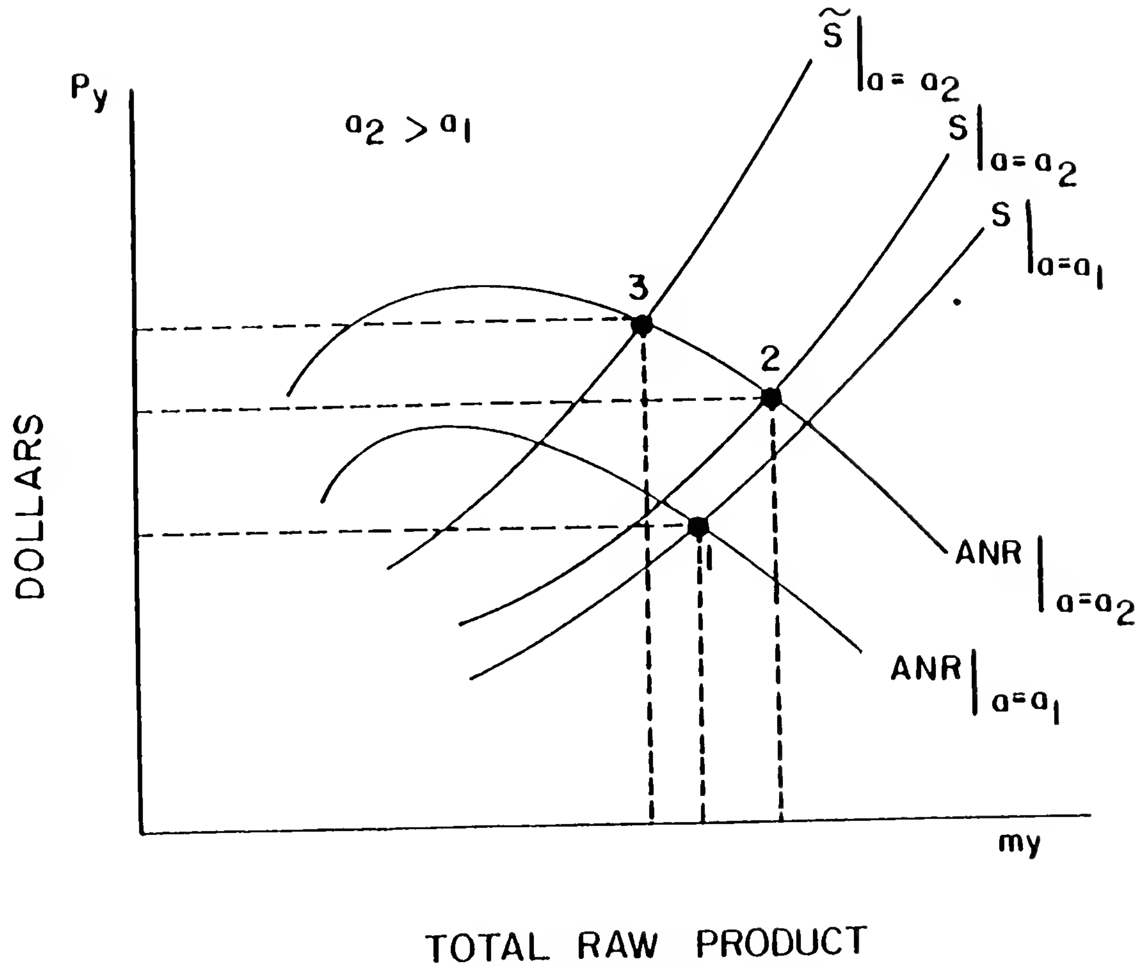

Figure 3.3. Equilibria Locations for Two Quality Levels.

is consistent: the raw material price must increase. This result is consistent with the fact that when the quality of raw product is improved, the raw product is worth more.[14]

Heterogeneous Membership

Membership structure is an important determinant of the performance of agricultural cooperatives. So far, the foregoing conceptual framework has disregarded differences among the members that compose the cooperative association. The assumption of membership homogeneity has sidestepped equity and redistributional effects that alternative arrangements imply when members are unequal.

Let Z denote the final product, Y the raw product, and let the relationship between Z and Y be given by[15]

$$Z = aY, \qquad (3.31)$$

where a is "the yield of Y," so that $0 < a < 1$. Let y_i denote the output of grower i, and as before, $Y = \sum_i y_i$. Then (3.31) becomes

$$Z = a\Sigma y_i. \qquad (3.32)$$

---

[14]Even though the present discussion has been limited to the case of nonjoint production (in characteristics and quantity), whether a coordinated case unidirectionally produces higher or lower levels of a characteristic depends on jointness of characteristics and on the importance of each characteristic on both the cooperative surplus and the members' cost.

[15]In many agricultural processing cooperatives, the role performed by the cooperative is the extraction of some characteristics from the raw product supplied by the members. Some examples are the extraction of raw sugar from sugarcane, oil and meal from soybeans, fat from milk, and juice from citrus crops. The mathematical form presented below is suitable to conceptually represent these processes.

Recall equation (3.1) where C(Z) is the variable cost of processing Z and FCC is the fixed cost of the cooperative. Assume the processing cost function is separable, so that the cost of processing each member's delivery can be allocated to that grower. Furthermore, since $Z = aY$ then $C(Z) = C(aY)$, and separability implies that

$$C(aY) = C[a \sum_i y_i] = \sum_i C(ay_i). \tag{3.33}$$

Let the fixed cost component of CS be apportioned to the members in some fashion. Allow for different "a" across growers so that $Z_i = a_i y_i$ and equation (3.33) becomes

$$C(Z) = \sum_i C(a_i y_i) \tag{3.34}$$

In the case of member heterogeneity, cooperative surplus is

$$CS = P_z \sum_i Z_i - \sum_i C(a_i y_i) - FCC. \tag{3.35}$$

Assume that the marginal processing cost is nondecreasing in its arguments so that $\partial C/\partial Z_i = \partial C/\partial a_i y_i > 0$. Based on the above framework where the raw product of the members is differentiated and a functional form for the cooperative processing is assumed, the impact of two payment schemes are analyzed below.

The Coordinated Case

For the coordinated case let the fixed cooperative cost be shared in a predetermined way. Given the assumption of separability, a coordinated system would pay PAY_i to member i for his deliveries. Then

$$PAY_i = P_z Z_i - C(a_i y_i) - \xi_i FCC, \tag{3.36}$$

where ξ_i is the share of cooperative fixed costs charged to member i.[16] Note that using equations (3.35) and (3.36), $\Sigma PAY_i = CS$. Grower's net returns π_i are given by

$$\pi_i = PAY_i - c_i(y_i, a_i) - FC_i \tag{3.37}$$

where $c_i(y_i, a_i)$ is the grower's variable cost of producing y_i with attribute a_i and FC_i is the fixed grower's cost. The grower's marginal cost is assumed to be nondecreasing in its arguments $\partial c_i/\partial y_i$, $\partial c_i/\partial a_i > 0$. Under a coordinated system (using payment defined in (3.36)) the grower's maximand (equation (3.37)) becomes

$$\pi_i = P_z a_i y_i - C(a_i y_i) - \xi_i FCC - c_i(y_i, a_i) - FC_i \tag{3.38}$$

To find the optimum level of production for grower i under a coordinated payment scheme, set the first partial derivatives to zero,

$$\partial\pi_i/\partial y_i = P_z a_i - [\partial C/\partial(a_i y_i)]a_i - \partial c_i/\partial y_i = 0 \tag{3.39}$$

$$\partial\pi_i/\partial a_i = P_z y_i - [\partial C/\partial(a_i y_i)]y_i - \partial c_i/\partial a_i = 0 \tag{3.40}$$

These partial derivatives have the usual interpretations. Assuming that the second order conditions are satisfied and that the system possesses a unique interior solution, solving (3.39) and (3.40) the optimal amount of raw product and quality level for each member is found at $y_i^* = Y_i(P_z,U,W,FCC)$ and $a_i^* = a_i(P_z,U,W,FCC)$, where U and W are parameters in the cooperative processing cost function and grower cost function respectively.

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[16]The assumption that every member has a predetermined cooperative fixed cost share, ξ_i, is for simplicity. ξ_i based upon each member's share of raw material is one particular criterion.

Payment Based on Raw Product

If payment is based on raw product, then define $\tilde{P}_y = CS/Y$ and

$$PAY_i = \tilde{P}_y y_i = (CS/Y)y_i \tag{3.41}$$

Using the payment definition given above, the grower's net revenue is

$$\pi_i = \tilde{P}_y y_i - c_i(y_i, a_i) - FC_i \tag{3.42}$$

The grower takes $\tilde{P}_y$ as a fixed, exogenous variable. Furthermore, since y_i is his only direct variable of interest, the grower will optimize only on y_i. Thus

$$\left.\frac{\partial \pi_i}{\partial y_i}\right|_{\tilde{P}_y = \text{const}} = \tilde{P}_y - \frac{\partial c_i}{\partial y_i} = 0. \tag{3.43}$$

It is instructive to compare this first-order condition to the first order condition for the grower under a coordinated payment system. Recall (3.39) and (3.40) and note that

$$MNR(y_i) = \frac{\partial CS}{\partial y_i} = P_z a_i - \frac{\partial C}{\partial a_i y_i} a_i, \tag{3.44}$$

$$MNR(a_i) = \frac{\partial CS}{\partial a_i} = P_z y_i - \frac{\partial C}{\partial a_i y_i} y_i. \tag{3.45}$$

In the case of a single attribute, one can see the similarity between the heterogeneous member and the homogeneous member cases. In a myopic cooperative, members equate average revenue with marginal cost (equation (3.43)) and in a coordinated cooperative members equate marginal revenue with marginal cost (equation (3.39) and (3.40)).

CHAPTER IV

EMPIRICAL PROCEDURES: AN APPLICATION TO SUGARCANE PROCESSING COOPERATIVES

This chapter presents a model to empirically test the theoretical model of the preceding chapter. A mathematical programming model is developed for sugarcane processing cooperatives which empirically describes the structure of a processing cooperative and the arrangements among its members.

Since straightforward maximization of members' profits would only provide the "coordinated" solution, it is necessary to advance beyond the total profit maximization objective. Particularly, the cooperative maximand must capture individual behavior given a set of structural arrangements.

The problem of scanning arrangements among cooperative members is analogous to problems faced by policy makers who must account for the actions of a myriad decentralized decision making units which take policy variables as given but also have their own objectives. Candler et al. (1981) have identified a potential and promising approach--multilevel programming--to deal with this class of problems. In the first level (higher hierarchy), policy makers optimize their utility function which depends on controllable variables (policies) and noncontrollable variables that are set at a second level. Then the units in the lower hierarchy try to select the level of variables in order to optimize their own objective. This nested optimization

approach is analytically propriate for the selection of "optimal" arrangements (policies) of cooperative members (second level), but its data requirements are beyond the scope of this study. Even the approach taken in this analysis is data intensive. The approach taken below is a subcase of the class problem discussed by Candler et al., where arrangements are set at a first level in a discretionary manner and members react in the second level where they make production decisions.

Florida Sugarcane Cooperatives

Sugarcane cooperatives offer a classical example of processing cooperatives for which data are reasonably available. In Florida, sugarcane processing cooperative associations account for about 35 percent of all cane processed (Zepp, 1976),[1] which is produced by members who have complete autonomy over cane production but are interdependent at harvest time when the jointly owned capital renders services of harvesting, hauling and processing the cane, and marketing the jointly produced sugar.[2] Quality of cane consists of extractable sugar and processing quality or fiber content (Meade and Chen, 1977). Cooperatively produced sugar is sold in terminal outlets which are relatively competetive, and thus the price of sugar received is exogeneous to the

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[1]The Florida sugar industry is located in the southern end of Lake Okeechobee and comprises more than 340,000 acres which produced 1,121,490 short tons of raw sugar in the 1980-81 season, supplying some 10 percent of the nation's consumption (Alvarez et al., p. 1982).

[2]Of much less economic importance, molasses and bagasse are by-products of sugar production. The cooperative member receives some additional payment from molasses sales, however, for the remaining of the study, sugar is considered as the sole output of sugar production.

cooperative. The cooperative as well as the members purchase inputs and services at given prices.

The core of arrangements of sugarcane processing cooperatives in Florida consists of (1) payment based on the amount of sugar delivered, adjusted with a fixed charge per ton of cane, (2) processing quota throughout the processing season, (3) members sovereignty in determining the volume and composition of deliveries, and (4) closed membership.

The prevailing payment arrangements among Florida sugarcane cooperatives entails the compensation of the grower by the amount of "net standard tons" of cane delivered for processing. This is an attempt to compensate for the amount of sugar, the final commodity, contained in the delivered raw material.[3] In brief, this payment method adjusts the volume of cane delivered by a qualitative factor which depends on the amount of sucrose (sugar) in the juice. Also, growers are charged a fixed fee which is the average harvest and transportation cost per ton of cane.

Pooling of processing costs that arise from differences in processing quality of cane does not provide equity because some members are overcompensated at expense of the others; such pooling does not provide stimuli to produce high processing quality cane either. Since sugarcane is perishable, storage can not be utilized and deliveries must be processed soon after harvesting. Therefore, the terms processing and

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[3]Cane delivered to the mill includes sugarcane, field trash and water. Field trash and cane tops are subtracted to obtain "net tons" of cane. "Standard tons" of cane are net tons of cane adjusted with a quality factor which is determined upon analysis of the sucrose content in the cane juice (Meade and Chen, 1977).

harvesting period can be used interchangeably. Processing time sharing is arranged by imposing delivery quotas upon each member so that the pattern of deliveries from each member is regulated on an equitable basis. Since sugar content increases as the season progresses, members would prefer to deliver their sugarcane as late as possible to obtain higher revenues. When the limited processing capacity forces the cooperative to extend the processing season, potential conflicts among the members regarding preferred delivery time are settled via quotas based on the weight of sugarcane.

Even though the flow of deliveries is regulated with processing quotas, the cooperative must process all members' deliveries. The members' sovereignty or discretion in determining the volume and composition of deliveries, under the prevailing arrangements, allows the possibility of individualistic strategic behavior and thus of a "myopic" equilibrium.

Production Environment and Value Added

The members of the cooperative have three tools to influence the character of their deliveries. First, they vary the intensity of the inputs used in a given area. Second, they adjust the area under cultivation for a given package of other input combinations. Third, they can select from an array of varieties of sugarcane which offer alternative packages of potential tonnage and qualitative values.

There are a number of alternative varieties that a grower may select for planting. Different varieties imply different strategies available to the grower with varying effects on the performance of the

individual and the cooperative. It is useful to look at this problem as one of choosing among alternative techniques of production.

There are at least four reasons for variation in the value added (surplus) generated by each variety. Varieties differ by (1) tons of cane produced per acre, (2) sugar content, (3) time to process, and (4) growing cost. All other factors can be computed from these four.

When one considers other crops that involve processing cooperatives, the production alternatives available to the grower may take different forms. In dairy farming, for instance, it may be a choice among different breeds of cows that involve varying production of raw milk, fat content, and costs. Choices may involve entire systems of production. One must bear this in mind in order to guard against generalizing too much.

A Mathematical Programming Model

The following discussion presents a mathematical programming model to provide solutions for a processing cooperative operation under alternative payment and processing arrangements. As suggested by Eschenburg (1971) and Ladd (1982), each cooperative structure is shaped by its own biological and economic environment. To empirically analyze the outcome of alternative arrangements then, it is appropriate to limit the discussion to a specific case--sugarcane processing cooperatives. The analysis does not fit all processing cooperative cases but it provides a framework for the central issues involved in the problem that this study addresses.

In this section, it is assumed that the time span for decision making allows for the selection of varieties of sugarcane for the fields to be planted. These are considered as the sole instruments that a grower uses to regulate volume and composition of deliveries. This is a simplication of all the agronomic tools that a grower uses to affect his deliveries. To formulate the problem mathematically and to include its temporal dimension, let the processing season be divided into T time periods of equal length (t=1,...,T). The characteristics that determine yields, costs and processing capacity use are unique to each field.[4]

Cooperative surplus (CS), the net surplus available for payment, is generated by the revenues from sugar sales less the cooperative costs incurred in providing the marketing and processing services to the members. Letting the cooperative surplus be separable in terms of the members' deliveries, CS can be written as

$$CS = \sum_i (Z_i) \qquad (4.1)$$

where CS_i is the cooperative surplus generated by grower i. The above equation implies that the cooperative processing cost is also separable in each members' deliveries. That is

$$C(Z) = \sum_i C(Z_i) \qquad (4.2)$$

where Z is the output sold by the cooperative (sugar) and Z_i is the output extracted from the delivery of raw material of member i. This equation in term implies that the fixed cooperative cost is apportioned

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[4]In Florida, a field is a well defined area (usually 40 acres). It is also the unit which the members use for decision making.

among the members. However, a payment scheme considered below departs from this to use amount of finished commodity as criteria to apportion fixed costs.

Consider fields, varieties of sugarcane and time to harvest as the sole instruments that a cooperative member uses for quantity-quality locational decisions. Cooperative surplus is given by

$$
\begin{aligned}
CS = \; & P_z * \sum_p \sum_i \sum_f \sum_t F_{pft} \; L_f \; Z_{pfti} && \text{Sugar sales} \qquad (4.3)\\
& -\sum_p \sum_i \sum_f \sum_t F_{pft} \; L_f \; C_1(Y_{pfti}) && \text{Less harvest cost}\\
& -\sum_p \sum_i \sum_f \sum_t F_{pft} \; L_f \; C_2(Y_{pfti} \; D_f) && \text{Less transportation cost}\\
& -\sum_p \sum_i \sum_f \sum_t F_{pft} \; L_f \; C_3(Y_{pfti}) && \text{Less processing cost}\\
& - FCC && \text{Less fixed cooperative cost}
\end{aligned}
$$

The notation and symbols used throughout this section are defined in Table 4.1. In other words, (4.1) and (4.3) imply that the marketing services are disaggregated into independent stages of production that are vertically integrated, and the identity of each member delivery is made in terms of generated costs and revenues.[5]

The payment problem for these cooperatives concerns the allocation of the cooperative surplus among the members. Because of the nature of cooperative associations, CS is entirely paid back to the members. Given the quality dimensions of sugarcane, three possible payment

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[5]If stages of production are appropriately defined so as to be independent except for the flow of raw material between them, each can be thought of as having its own production function (French, 1977). By duality and given input prices, each stage can have a "separate" cost function. The implication of staged cost structure is that total cooperative cost is the aggregation of costs incurred at each stage.

Table 4.1. Notation Used in the Mathematical Programming Model for Sugarcane Processing Cooperatives.

Notation	Definition
i =	1,....,m members
F_i =	Number of fields that belong to member i
F =	$\sum_i F_i$ = total number of fields
F_{pfit} =	1 if field f_i that belongs to member i is planted with variety p and harvested in period t, 0 otherwise.
f =	1,...., F_i fields that belong to member i.
t =	1,...., T processing periods.
p =	1,...., P varieties of sugarcane.
P_z =	Per ton price of sugar net of marketing cost
L_f =	Area of field f in acres.
Z_{pfti} =	Tons of sugar produced per acre in field f with variety p delivered in time period t by member i.
Y_{pfti} =	Tons ofsugarcane per acre produced in field f with variety p delivered in time period t by member i.
D_f =	Distance in road miles from field f to processing plant.
$M^u{}_t$ =	Mill upper capacity in period t defined in ton of sugarcane.
$Q^u{}_{it}$ =	Maximum volume of deliveries to be processed in time period t for member i.
V_p =	Variety p of sugarcane.
C_1 =	Harvest cost per ton of sugarcane.
C_2 =	Transportation cost of a ton of sugarcane from a given field to the processing plant.
C_3 =	Processing cost per ton of sugarcane of variety p.
C_{pfi} =	Cost per acre of growing cane of variety p in field f by member i.
FCM =	$\sum_p \sum_i \sum_f \sum_t F_{pft} \; L_f \; FC_f$, i.e., members' total fixed costs.

Table 4.1 (Continued)

Y	=	$\sum_p \sum_i \sum_f \sum_t F_{pft} \; L_f \; Z_{pfti}$, i.e., total cane produced by the cooperative.
Z	=	$\sum_p \sum_i \sum_f \sum_t F_{pft} \; L_f \; Z_{pfti}$, i.e., total sugar produced by the cooperative.
M_{it}	=	$\sum_p \sum_i \sum_f \sum_t F_{pft} \; L_f \; Y_{pfti}$ i.e., total cane processed for the member in period t
C_m	=	$\sum_p \sum_i \sum_f \sum_t F_{pft} \; L_f \; C_{pfi}$, i.e., members' total variable cost.

systems seem plausible: (1) payment based on raw product weight, (2) payment based on weight of the finished product extracted, and (3) payment on recoverable finished commodity adjusted for the cost of marketing and processing the cane. The foregoing model allows more complex payment schemes, such as partial pooling of harvesting, transportation and processing costs, but to avoid confusion only the above payment systems are operationalized. Given that a payment system has been defined, the next step to develop in the model is to state the cooperative maximand under a given payment system. Under the payment systems considered, the cooperative strives to maximize total net returns in all cases. However, nested in the cooperative maximand is the member maximand in which a payment scheme is regarded as exogeneous in the decision to plant a field, with what variety and in what period to make the delivery. Because the price or payment is endogenous to the cooperative but the individual member regards it as exogeneous when he evaluates the fields of sugarcane, the problem is a subcase of the bilevel programming problem presented by Candler et al. (1981). Even though the payment policies are discerned as discrete, the individual member behavior is simulated as a nested optimization taking the pricing policies as given. However, the actions are recursive and interactive among the members until equilibrium is reached.

Payment Based on Raw Product

Consider the first payment system where members are paid based on tonnage of raw material delivered (Y). A price (P_y) per unit of Y is

$$P_y = CS/Y \tag{4.4}$$

and the payment to grower i for the delivery of y_i is

$$PAY_i = P_y \, y_i \tag{4.5}$$

Notice that P_y is the same for all growers.

This payment implies the pooling of the qualitative dimensions of sugarcane delivered and of all cost components of CS (equation 4.3). In a myopic cooperative, P_y is viewed as given at the individual member level. However, P_y is endogeneous to the cooperative system.

Processing plant capacity is defined by the amount of cane that can be economically processed in every period of the season. There are two limits to be considered: a lower limit which specifies the minimum amount of cane that justifies an economic operation of the mill, and an upper limit which specifies the maximum amount that can be processed in a given period.

Given that the members behave myopically, the cooperative strives to maximize total net returns subject to the mill and quota constraint and the myopic equilibrium condition. That is to maximize

$$P_y \, Y - C_m - FCM \qquad \text{Total net returns} \qquad (4.6)$$

subject to

$$Y < M^u \qquad \text{Mill upper capacity} \qquad (4.7)$$

$$Y > M^l \qquad \text{Mill lower capacity} \qquad (4.8)$$

$$M_{it} > Q^u_{it} \qquad \text{Member upper quota} \qquad (4.9)$$

$$M_{it} < Q^u_{it} \qquad \text{Member lower quota} \qquad (4.10)$$

$$CS/Y - P_y = 0 \qquad \text{Myopic equilibrium} \qquad (4.11$$

The notation is defined in Table 4.1. Equation (4.11), the last constraint, guarantees myopic equilibrium and that the cooperative surplus is exhausted (P_y Y = CS = total payment).

Payment Based on Finished Product

Next, consider the arrangement in which members are paid for the amount of finished product (Z_i) that is extracted from his delivery of raw product (y_i). The price is based on Z rather than on Y and it can be expressed as

$$\tilde{P}_z = CS/Z \tag{4.12}$$

and the payment to grower i is

$$PAY_i = \tilde{P}_z \, Z_i \tag{4.13}$$

By defining $P_{yi} = \tilde{P}_z \, (Z_i/y_i)$, a price per unit of Y_i can be calculated. In this method, a constant per unit price of finished product is determined for all growers but the per unit price of the raw product differs. The term Z_i is the "finished product equivalent." The structure of the maximand of a myopic cooperative using this payment system is given by maximizing

$$\tilde{P}_z \, Z - C_m - FCM \qquad \text{Total net returns} \tag{4.14}$$

subject to

(4.7), ..., (4.10) Above constraints

$$CS/Z - \tilde{P}_z = 0 \qquad \text{Myopic equilibrium} \tag{4.15}$$

The notation definitions are given in Table 4.1.

The Coordinated Cooperative

Last, consider the case where the growers are paid on a use value basis. Thus, they are paid the quantity of finished product extracted from their delivery of raw product adjusted for the cost of processing. The "use value" of delivery of a member is

$$P_z Z_i - C(Z_i) \tag{4.16}$$

Under fully coordinated behavior, the grower's payment PAY_i is the use value, hence,

$$PAY_i = P_z Z_i - C(Z_i) \tag{4.17}$$

The mathematical structure of this problem is by maximizing

$$CS - C_m - FCM \qquad \text{Total net returns} \tag{4.18}$$

subject to

(4.7) and (4.8) As above.

If each delivery is evaluated individually according to the cooperative surplus it generates, the solution of the problem provides a "coordinated" solution given the preceding assumptions.

Processing Arrangements

Nonquota arrangements can be simulated by releasing the members upper and lower quotas constraints (equations 4.9 and 4.10) in any of the above problems The performance implications can be evaluated from the solution. More complex arrangement schemes can be simulated with permutable combinations of quota arrangements and alternative payment arrangements.

Estimation of Parameters and Data Management

To make the above model operational, its parameters must first be estimated. Such parameters consist of the price of raw sugar, sugar yields, cooperative and members' costs, and those concerning the structure of the cooperative such as the members relative and absolute size, a measure of the processing capacity and usage, and the relevant arrangements among the members.

Estimations of Yields

The first step to operationalize the mathematical model is to estimate the quality, yields and raw product produced with the varieties of sugarcane. These estimates are direct input into the cooperative surplus to be generated. More specifically, the objective here is to estimate Z_{pfti} and Y_{pfti} of equation (4.3).

In Florida, sugar content (the extractable characteristic) in the cane generally increases as the processing season progresses due to the progressive influence of cool temperatures. Given the relationship between sugar produced and raw material, and following Alvarez et al. (1982) for the specification of environmental variables to be included, a conceptual model for the amount of sugar per acre (Z) is

$$Z = PRS\ NT \tag{4.18}$$

$$PRS = PRS(B, Z^{x}, Z^{prs}) \tag{4.19}$$

$$NT = NT(B, Z^{x}, Z^{nt}) \tag{4.20}$$

where B is a vector such that

$$B = (PAY, W, t, V, M, Y, MODE, Age, s, SUN, F, TEMP)$$

Appendix B summarizes the presentation of Alvarez et al. (1981) of the specification of most variables included in the above model. The notation of the above model is described in Table 4.1.

Because of its scope, this study is limited to predict rather than explain the sugar yields of different fields to operationalize the mathematical model. Given that the structure of arrangements has remained fixed for the period of observation (e.g. payment system), yields, management and variety selection are in part or indirectly determined by such arrangements. This has implications for the use of estimates of equations (4.19) and (4.20) for the analysis of alternative marketing arrangements.

Primary cross-section and time series data for the variables of Table 4.1 were collected from a sugarcane cooperative located in South Florida. This information consists of sugarcane field data and also information concerning the structure and policies of the cooperative. Secondary data were obtained from weather reports.

The observation interval encompasses nine years (1971 to 1979). The sampling procedure resulted in 5,300 observations, each observation consisting of the event of a particular field for a given year. From this sample, a restricted sample of 4,384 observations was obtained by eliminating observations with varieties whose frequency was less than 30 or that were missing relevant information. The data embody 888 microsamples—each microsample being the set of observations of a particular field.

Table 4.2. Notation Used in the Specification of Yield Models.[a]

Notation		Definition
Z	=	Tons of sugar produced per acre.
PRS	=	Percent of recoverable sugar.
NT	=	Net tons per acre.
PAY	=	Payment scheme arranged by the cooperative.
W	=	A vector of input prices used in sugarcane production.
t	=	A subscript denoting the period of the season.
V_p	=	Variety P of sugarcane.
MAN_i	=	Management of the ith member.
Y	=	Year of crop cycle.
MODE	=	Mode of harvest (mechanical or by hand).
Age	=	Age of cane since planting or last harvest.
s	=	Soil quality.
SUN	=	Solar radiation.
F	=	Freeze.
TEMP	=	Temperature during growing season.
Z^x	=	Other economic factors that affect sugarcane composition such as members behavior, risk aversity, arrangements.
Z^{prs}	=	All other variables that affect PRS_t assumed constant.
Z^{nt}	=	All other variables that affect NT_t assumed constant.

[a]Alvarez et al. (1982) presents a detailed discussion for the inclusion of the agronomic and environmental variables which was briefly summarized in Appendix B.

Ordinary least squares was applied to pooled data to obtain the estimated statistical models presented below.[6] Given the large number of regressors, a search for functional form is fruitless and it is assumed that all statistical models are linear.

The regressors are defined in Table 4.3. Class variables are used for the distinction of cooperative members, variety of cane and mode of harvesting. The remaining variables are treated as covariates. Since the PRS (percent of recoverable sugar) and NT (net tons of cane) equations have similar set of regressors, Zellner's seemingly unrelated regression technique offers little advantage over ordinary least squares. The specification of the statistical models is based on the work of Alvarez et al. (1982).

The coefficients for the estimation of percent of recoverable sugar, the extractable characteristic, are presented in Table 4.4. The

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[6]The data collected for the estimation of the statistical models of tonage and sugar yields contain information in both a time series and a cross sectional form. A crucial decision is to determine how to combine these two types of information in a statistical model in order to best predict and to learn about the parameters generating the data. Thus, the problem is whether or not to pool the micro samples of each field, and if so to what extent. Ideally, data should be pooled only if the cross sections (fields) were identical. If not, the choice of an appropriate estimation technique depends on what assumptions are made about the intercept coefficient of each cross section. If spherical random errors are associated with the intercept of the cross sections, a random effects or error component model should be estimated. If the intercepts of the cross sections are assumed to be fixed parameters, the dummy variable or covariance model should be estimated (sometimes called fixed effects). Here, the model estimated is assumed to be a subcase of the latter where the dummy variable coefficient are equal to each other. In other words, to properly apply ordinary least squares to pooled data, it is assumed that the data generate spherical distrubances in the sense that they are homoskedastic, cross-sectional independent and serially uncorrelated. Judge et al. (1982) address the issues and implications of different pooling schemes.

Table 4.3. Notation Used in the Regressions for Predicting Percent Recoverable Sugar and Net Tons of Sugarcane.

Notation		Definition
Age	=	Age of cane in periods of two weeks up to November 1 of foregoing processing season.
F	=	Freeze degrees defined as the number of hours times the number of integer degrees at/or below 33°F during the foregoing processing season.
MAN_i	=	1 if the field is controlled by member i of the cooperative, 0 otherwise.
MILE	=	Distance in miles from Lake Okeechobee to the field, a proxy for soil depth.
MODE	=	1 if the field is mechnically harvested, 0 otherwise.
NT	=	Net tons of cane per acre.
PRS	=	Percent of recoverable sugar.
SUN	=	Solar radiation as average langley units from April to October of current year.
t	=	Harvest period in four-week intervals.
TEMP	=	Temperature in degree days defined as the number of degrees by which the monthly average temperature exceed 60°F from April to October.
TREND	=	1 if observation occurs in 1971, and k + 1 if observation occurs k years after.
V_p	=	Variety p of sugarcane.
Y	=	Year of crop cycle.

Table 4.4. Estimated Coefficients and Selected Statistics for the Predicting Percent of Recoverable Sugar.[a]

Dependent variable: PRS

Intercept	Age	F	F^2	Day	Day^2	MAN_2
7.64	-0.146	0.004	-0.00002	-0.03	0.0005	0.18
(8.31)	(-6.62)	(-6.62)	(-10.14)	(-5.96)	(12.94)	(6.35)
MAN_4	MAN_6	MAN_7	MAN_9	MAN_{10}	MAN_{11}	MILE
0.24	0.36	0.44	0.21	0.16	0.12	-0.02
(4.94)	(4.25)	(5.60)	(3.30)	(1.98)	(1.55)	(-5.96)
MODE	SUN	t	t^2	t^3	TEMP	TREND
-0.30	-.009	-0.65	0.30	-0.03	0.28	-.10
(-11.12)	(-10.16)	(-4.66)	(6.45)	(-6.78)	(7.63)	(-14.15)
V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	$t*V_2$	$t*V_5$
0.11	-0.45	-0.99	-0.17	-0.81	0.13	0.20
(1.64)	(-2.84)	(-2.71)	(-1.41)	(-3.08)	(8.48)	(3.06)
$t*V_6$	$t*V_7$	$t*V_9$	$t*V_{12}$	$t*V_{13}$	$y*V_{14}$	Y
-0.05	0.12	-0.04	0.21	0.11	0.31	-0.02
(-1.90)	(3.20)	(-2.11)	(2.60)	(3.30)	(4.09)	(-1.01)

R^2=0.33 F-ratio = 55.29 n = 4584

Mean Square Error = 0.53

[a]Symbols are defined in Table 4.3. Below the estimated coefficients the corresponding t-ratios are presented in parentheses.

signs and magnitudes of coefficients conform with *a priori* expectations, and are generally consistent with the results of Alvarez et al. (1982). A relevant finding is the significant effect of the time of harvest (t) on PRS and a well defined tendency of PRS to increase as the processing season progresses. In general, varieties have significantly different effect on PRS.

The coefficients for the estimations of net tons per acre are presented in Table 4.5. The results are also consistent with the findings of Alvarez et al. (1982). Varieties of cane and members are significantly different in the way they affect net tons of cane produced per acre.

Processing and Cooperative Structures

As pointed out by Eschenburg (1971), it is important to describe the structure of the cooperative since the behavior of the members is largely determined by the organization structure.

The cooperative under study processed sugarcane from 800 fields with a daily processing capacity of 7,140 tons of cane operating 140 days of the 1979-80 processing season (or equivalently, processing capacity is about 1,000,000 tons of cane for the season). To simplify the structure of the problem, the membership of the cooperative is assumed to consist of five growers, selected at random, and each owns 160 fields. The five most frequent varieties in the 1979-80 season are selected as finite possibilities available to a grower face. These varieties actually accounted for 98 percent of the area harvested in the 1979-80 season by the cooperative. The processing season is divided into five harvest periods, each encompassing four weeks, within which the quota and the mill capacity are defined.

Table 4.5. Estimated Coefficients and Selected Statistics for Predicting Net Tons per Acre.[a]

Dependent variables: NT

Intercept	AGE	F	F^2	DAY^2	MAN_3	MAN_4
-41.46	0.44	0.02	-0.00007	0.001	-2.58	-1.65
(-5.36)	(14.46)	(3.76)	(4.77)	(6.87)	(9.23)	(-3.68)
MAN_5	MAN_6	MAN_8	MAN_9	MAN_{10}	MILE	SUN
2.83	-1.92	-3.28	-1.67	5.50	-0.06	0.08
(5.70)	(-2.44)	(-2.78)	(-2.86)	(7.08)	(-1.47)	(9.50)
t	t^2	TEMP	TREND	V_1	V_2	V_3
4.75	-0.62	1.36	-1.11	40.14	5.00	-18.86
(10.58)	(-9.52)	(4.40)	(-17.99)	(5.00)	(3.55)	(-10.14)
V_5	V_6	V_7	V_9	V_{11}	V_{12}	V_{14}
-3.26	-17.98	-2.68	-2.61	21.54	12.19	14.91
(-4.27)	(-4.20)	(-2.03)	(-4.52)	(3.24)	(4.87)	(3.45)
$t*V_1$	$t*V_3$	$t*V_6$	$t*V_{11}$	$t*V_{13}$	$t*V_{14}$	V^1*Y
-4.17	2.19	2.94	-2.63	-0.61	-2.16	-9.09
(-3.72)	(6.76)	(3.47)	(-2.86)	(-3.14)	(-2.63)	(-2.10)
V_3*Y	V_4*Y	V_6*Y	V_7*Y	V_9*Y	$V_{10}*Y$	$V_{11}*Y$
3.00	2.01	4.50	3.81	1.99	1.36	-5.11
(6.77)	(8.04)	(4.84)	(4.99)	(8.36)	(4.65)	(-2.62)
$V_{12}*Y$	$V_{13}*Y$	$V_{14}*Y$	Y			
-2.51	0.59	-2.54	-4.05			
(-2.67)	(2.02)	(-2.57)	-20.25)			

$R^2 = 0.54$ F-ratio = 110.00 n = 4584

Mean Square Error = 45.21

Mean NT = 34.62

[a]Symbols are defined in Table 4.3. Below the estimated coefficients the t-ratios are presented in parentheses.

The total tonnage (net tons) that accrues to each member is divided into the number of periods to obtain a point estimation for the delivery quota. An interval is defined by a lower and an upper limit in net tons within which the member must deliver each period. The upper and lower limits of the processing plant and members' quotas are specified such that they remain the same throughout the period.[7]

Estimation of Costs

The next step to operationalize the mathematical programming model is to develop a cost function for the cooperative. An informal approach is taken to estimate the cost components of cooperative surplus (C_1, C_2, and C_3 in equation 4.3) and to estimate the grower's cost function. Primary cost data were collected via a survey among cane factories and researchers in the area. The responses were complemented with secondary sources. All cost figures below are expressed in December, 1981, prices.

The processing cost function is specified such that the marginal cost of processing cane is equal to the average variable cost indexed by a processing quality factor which depends on the variety of sugarcane. Viewing a variety of cane as providing a specific grade of processing quality characteristics, the specified marginal processing cost is

$$mc = \partial C_1 / \partial NT = \alpha\beta_p$$

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[7] In reality these parameters are vulnerable to the influence of stochastic variables (weather may delay raw material delivery) and equipment breakdowns. For our purposes this abstraction presents no serious problem.

where α is a constant, β_p a processing time index which depends on variety p. Then total processing cost is

$$TC\ (NT) = \int_0^{NT} \alpha\ \beta_p\ dNT = \alpha\ \beta_p NT + FC_1$$

where FC_1 is the fixed processing cost by definition of $TC(0) = FC_1$ (denoted previously as FCC). This specification implies a variable processing cost function linear in the volume of sugarcane in any time period.

An estimate of α is obtained with the USDA (1981) estimate of average variable processing cost for Florida. Fixed processing cost is obtained by using the seasonal processing capacity of the cooperative (1,000,000) tons and the USDA's (1981) estimate of fixed processing cost per ton of cane in Florida.

Even though the importance of processing quality of the different varieties was recognized in the survey, primary data were not available. Some survey answers suggest that fiber content (processing quality) in sugarcane is highly correlated with varietal correction factors (VCF's) used in experimental milling tests which have been computed in South Florida.[8] The estimated β_p's for the selected varieties are presented in Table 4.6.

The cost of (hand) harvesting, hauling and transloading a "gross" ton of sugarcane was estimated by the cooperative manager to be $7.14.

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[8]See Miller and James (1978) for an explanation of VCF's. Some mills in the area use these VCF's in their decision of what varieties to grow or when paying the independent growers for sugarcane.

Net tons predicted in Table 4.5 and 4.6 are adjusted to "gross tons" of cane with a factor of 1.05.[9]

Table 4.6. Comparison of Varieties of Cane in the Mathematical Programming Model.[a]

Variety	Cost index: Processing (B_p)	Cost index: Growing (E_p)	Sample mean: NT	Sample mean: PRS
A	1.16	0.97	49	9.3
B	1.18	0.80	37	10.0
C	1.28	0.70	37	9.1
D	1.28	1.10	36	9.3
E	1.00	1.00	34	9.6

[a]Varieties A, B, C, D and E correspond to V_1, V_2, V_7, V_9, and V_8, respectively, in Tables 4.4 and 4.5.

Supplies of raw agricultural products handled by a cooperative are usually acquired from dispersed points. There is a need to incorporate the spatial components of marketing cost associated with the raw material delivered by the members, especially when considering alternative arrangements that deal with schemes for regulating of the members' volume. Though in the case of Florida sugarcane cooperatives the members are located in a relatively compact geographic region, sugarcane is a very bulky commodity. For the 1981-82 season, the cooperative under study contracted transportation at a fixed charge of $0.35 per ton and $0.15 per ton per mile travelled.

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[9]Recall footnote 3. What is harvested and transported is gross tons of cane, not net tons of cane that are processed. A factor of 1.05 is applied for trash, tops, leaves, and water to adjust the predicted net tons of sugarcane to gross tons of cane. A factor of 1.5 is applied to convert air miles to road miles in estimating transportation cost.

Regarding the grower's cost the survey revealed that variable cost per acre differs among varieties of sugarcane. Unfortunately, no consistent data exist for the different varieties of sugarcane regarding these costs. Assume that the growing cost function is

$$C_p = CPA \cdot E_p \tag{4.24}$$

where CPA is the variable expenses of growing per acre of cane, and E_p is the (survey average) cost index associated with growing variety p of sugarcane whose estimates are presented in Table 4.6.

Summary of Estimations

The parameter estimates for the mathematical programming problems presented in equations (4.6) through (4.17) are summarized in Table 4.7. In brief, statistical models are used to predict sugar yields and tons of cane per acre on a field basis for the different varieties. The cost components of the cooperative surplus and the grower cost function are estimated for the varieties. The varieties, fields, size of the cooperative and processing capacity are obtained from an actual cooperative operating in South Florida.

Implementation of the Model

When confronted with large-scale problems, agricultural economists soon learn about the limitations of traditional solution techniques that are widely used in the profession. One example is the almost exclusive use of linear programming (simplex method) which has characterized several generations of agricultural economists. Here, the choice of a

Table 4.7. Parameter Estimates for the Mathematical Programming Model for the Sugarcane Processing Cooperatives.

Parameter	Estimates	Description	Source
P_z	\$480	Price per ton of raw sugar	USDA
a_1	PRS	Percent of recoverable sugar	Table 4.4
y	NT	Net tons of cane/acre	Table 4.5
Z	PRS*NT	Tons of raw sugar	Above
L			
f	32	Acres of field f	Sample average
$C_i(y, a_1, a_2)$	$C_p = 450 * E_p$	Variable growing cost per acre	USDA and Table 4.6
$C_1(y)$	7.15*NT	Harvest cost per ton	Cooperative
$C_2(y, D_f)$	$(6.37 + .15D_f)$NT	Per ton transportation cost	Cooperative
$C_3(y, a_2)$	$6.54 * \ {}_p * NT$	Variable processing cost per ton of variety p	USDA and Table 4.6
FCC	\$8,620,000	Fixed capital cost of a mill of 7,140 tons of daily capacity	USDA
FC_f	$\$A_f * 275$	Fixed cost of growing cane per field	USDA
FCM	$\$ \ {}_{f} \ FC_f$	Total members fixed cost	Above
M^l_t	160,000 tons	Four-week mill lower capacity in tons of cane	Cooperative
M^u_t	200,000 tons	Four-week mill upper capacity in tons of cane	Cooperative
Q^u_{it}	40,000	Four-week member upper quota in tons of cane	Cooperative
Q^l_{it}	50,000 tons	Four-week member lower quota in tons of cane	Cooperative

solution technique is critical given the large dimensions of the problem.

The problems stated in equations (4.6) through (4.18) are integer programming problems (F_{pfit} integer) and the use of the simplex method will not insure integer solutions. However, there are alternative approaches to solve the above integer programming problems. Specifically, the problems can be viewed as two-stage assignment problems (see Appendix C for an illustration). In the first stage, varieties are assigned to fields on a single processing period basis. Then, variety-fields are assigned to a harvest period. The assignment and assignees are matched in such a way that the cooperative objective is maximized while satisfying the constraints.

The problem also falls into the class of capacitated transshipment problems. Regardless of the physical context of the application, the transshipment problem and the assignment problem can be formulated as equivalent transportation problems (Hillier and Lieberman, 1980). With 800 fields, five processing periods, five growers and five varieties of sugarcane, the resultant transportation problem consists of some 20,000 activities.

The capacitated transshipment problem and its specialization (the transportation problem and other related problems) can be expressed as network flow problems (Bradley et al., 1976). The specific adaptation of the above problem to a network flow framework is briefly explained in Appendix C. The mathematical programming problem developed above was solved as a network flow problem with the program presented in Appendix D and the performance results in the following chapter.

CHAPTER V

EMPIRICAL RESULTS AND DISCUSSION

This chapter presents the empirical results of the model presented in Chapter IV which employs sugarcane processing cooperatives as a specific example to test the conceptual model developed in Chapter III. Unfortunately, there are no studies to compare with the results presented below. The empirical results concerning the estimation of parameters of the mathematical programming model were presented in the previous chapter. The focus is on the results from the runs of the various mathematical programming problems. First, performance concepts and measures to evaluate the arrangements are briefly discussed and defined. Then the performance results are presented, compared and discussed for alternative arrangements among cooperative members along with a sensitivity analysis for selected structural parameters. Last, the implications of the results and their relation to the conceptual developments are integrated into an overall assessment.

The Performance Measures

Performance is such an elusive term that any attempt to measure it should be preceded by an attempt to define it. Helmberger et al. (1977) defined the performance of a firm as the *ex post* value of choice variables appearing in the profit function of the firm as envisaged in economic theory. Thus, output and price levels embody the performance

of a firm if they are influenceable. They define market performance as the total performance of all its participants, including all prices that vary with the level of output. Beyond its definitional problem, the performance measurement problem remains even for well-defined performance dimensions.[1]

To evaluate the performance impact of alternative arrangements, norms of comparison are required. Clearly, the ideal norm is the "coordinated" cooperative solution since conceptually it represents a potential Pareto optimal allocation. A necessary condition for a Pareto improvement is an increase in total net returns under a given set of arrangements relative to another set.

The allocative efficiency objective is the maximization of total net returns to the operation of the cooperative. The results deal with two aspects of equity. One is the distribution of net returns among the members measured with the coefficient of variation (ratio of standard deviation over the mean). The coefficient of variation (C.V.) measures the degree of relative dispersion of net returns. However, it measures the degree of inequality rather than inequity.[2] The second aspect of equity regards payment equity or how well members are compensated in accordance with the value of their deliveries measured with a price

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[1]Lang et al. (1982) identified two difficulties associated with measuring performance: first, the difficulty of measuring performance directly; second, the problem of comparing the importance of one dimension relative to another remains even if all dimensions of performance in a commodity subsector were quantified.

[2]Discerning between equal vis-a-vis equitable treatment of the members is one of the most perplexing problem that cooperatives face. Both terms can be regarded as equivalent only if members are indeed equal.

accuracy index (PAI). This index, whose specification is original in this study, is intended to measure the degree of distortion between payment to the growers and the cooperative surplus that they generate. The computed values will always be $< = 1.0$, where 1.0 is perfectly accurate pricing. The index provides a measure of pricing equity and the degree of free riding since PAI<1 implies that some members are overpaid at the expense of others. The price accuracy index, then, is measured as

$$PAI = \frac{Y_i}{Y} \; \frac{CS_i - \left| CS_i - PAY_i \right|}{CS_i}$$

where y_i is amount of raw material delivered by member i, Y the total amount, CS_i is the cooperative surplus generated and PAY_i is the payment from the deliveries of member i. Thus, PAI is the weighted sum of the pricing accuracy of each member's deliveries, where the weights are the shares of raw product of the members. This study emphasizes allocative efficiency, and although net returns and pricing equity are measured, the definition of an optimal or ideal equity values and the weights attached to the different measures of performance is not attempted.

Based on the definition of performance given by Helmberger (1977), the average net revenue product or average price per ton of sugarcane (P_y) and the amount of (tons) of sugarcane and sugar produced are measured. Many other measures can be computed from the solutions of the model (e.g. net returns per acre, average price per tons of cane and quasirents), but given magnitude of results, concentration is placed on the above measures.

Baseline Results and Discussion

The focus of this section is the presentation and discussion of baseline results with the parameters estimated in the preceding chapter. The productivity coefficients of the five members that compose the cooperative coorespond to those of MAN_1, MAN_6, MAN_7, MAN_8, and MAN_{10} of Tables 4.4 and 4.5. The performance measures computed from the solutions are presented in Table 5.1. Differences in the performance results under alternative arrangements are due to differences in the pattern of deliveries, varieties grown and area of cane planted by each of the members. The latter two are reported in Table 5.1.

The coordinated cooperative makes total net returns of $4,648,126 for a single processing season, the highest of all the scenarios considered. The coordinated solution does not utilize members' quotas since it implies that members are perflectly coordinated in order to achieve collectively maximum net returns with no regard to individual net returns or quotas. The higher net returns of the coordinated solution are due to the collective selection of varieties, fields and periods of delivery to maximize collective rather than individual net returns. This result represents a favorable central test of the theoretical model. Payment based on sugar delivered with processing quotas ranked second with total net returns of $2,304,719 which represents a loss of $2,343,407 from the coordinated solution due to the invididualistic (myopic) behavior of the cooperative members. Payment based on the amount of raw product (sugarcane) with processing quotas resulted in $2,251,238 total net returns. This represents a loss of $2,396,888 from the coordinated solution and it was due to individualistic behavior of

Table 5.1. Results of Performance Measures of Alternative Marketing Arrangements for Sugarcane Processing Cooperatives

Performance measure	Payment based on: Raw product		Payment based on: Finished product		Coordinated cooperative
	Quota	Nonquota	Quota	Nonquota	
Net returns					
Total	2,251,238	1,990,765	2,304,719	2,333,519	4,648,126
Member 1	447,421	390,098	395,708	430,778	730,574
Member 2	277,892	201,116	341,602	278,554	840,714
Member 3	440,081	398,523	545,957	530,246	1,154,149
Member 4	159,580	107,474	105,611	-73,937	357,173
Member 5	926,265	893,555	915,842	1,167,879	1,565,517
C.V.	0.65	0.73	0.64	0.98	0.49
Pricing accuracy (PAI)	0.948	0.940	0.967	0.903	1.0
Raw product price ($/ton)	17.00[a]	16.72[a]	17.08	17.12	20.68
Sugar price ($/ton)	174.95	172.32	175.34[a]	175.56[a]	210.63
Raw product (tons)	908,153	888,071	906,863	905,235	985,833
Sugar (tons)	88,273	86,160	88,326	88,261	96,780
Varieties[b]	C	C	C	C	C,B
Acres of cane	24,960	24,224	24,896	24,932	25,600

[a]These are equilibrium prices in their respective payment arrangements. These "prices" satisfied equations (4.11) and (4.15) respectively. Thus the prices represent the average net revenue of the cooperative either in terms of tons of sugarcane or tons of sugar delivered.

[b]The varieties are listed in order of their frequency in the solutions. Except in the coordinated case, in all the scenarios variety C was the only variety in the solutions. In the coordinated case variety C was in 82 percent of the fields planted and variety B was in 18 percent of the fields planted.

the members. When looking at the individual members, some results are interesting. Some members benefited positively with cane-based payment rather than with sugar-based payment and vice versa. For example, member 3 is better off with sugar-based payment than with cane-based payment by $105,876, while member 4 is better off with cane-based payment by $53,969. The redistribution of impact of alternative payment schemes is not surprising since individual members have comparative advantages in producing cane or sugar. However, all the members are better off under a coordinated payment scheme than any other scheme.

The coefficient of variation of net returns of the members under a coordinated payment scheme was the smallest (C.V. = 0.49). Sugar-based price with quotas offered the second smallest coefficient of variation (0.64), and tonnage-based payment with processing quotas offered was ranked as third in profits variation (0.65). The imposition of quotas in the presence of myopic behavior of the members in both sugar-based and cane-based payments, reduced the variation of profits among the members. Thus, in the cases considered quotas represented an improvement in equity (equality) in the distribution of net returns. With sugar-based payment allocative efficiency increased slightly, however its coefficient of variation went up dramatically due to the change in the relative distribution of profits. For instance, note that member 1 and member 5 increased their net returns while other members decreased theirs when quotas were removed.

The results also indicate that quotas, under individualistic behavior of the members, can improve coordination among the members. For instance, total net returns were $260,473 higher with processing

quotas than without them in cane-based payment. Though in sugar-based payment the removal of quotas led to higher net returns, the design of appropriate quality specification and volume quotas can induce cooperation as in the case of cane-based pricing. The amount of raw product delivered as well as the amount of sugar produced were higher with members having processing quotas. The result of cooperation being induced with quotas is supportive of Hobbes' (1909) suggestion about the possibility of achieving a preferred outcome by coercion.

The difference in total net returns between cane-based and sugar-based payments in the presence of quotas is $45,951. This difference is not as dramatic as one could expect. Three reasons are envisioned to provide, in part, an explanation. First, the variety-choice selection used in the optimization runs may not allow larger variation in quality-quantity choice. The performance implications with alternative quality choice specification is explored later in the sensitivity analysis. Second, the amount of sugar and the amount of cane are not independent. However, higher amount of cane tonnage does not imply higher amount of sugar, since sugar also depends on the sugar content of the delivered cane. Third, even if at first glance sugar may seem a more plausible payment unit, this perception appears increasingly inaccurate when one considers that processing costs (as well as transportation and harvesting costs) are directly dependent on the volume of deliveries and not on the amount of sugar delivered. In the presence of myopia, highly productive growers (high-sugar content, low-cane tonnage) are penalized for their deliveries which in turn leads to underproduction as in the case of externalities.

The results are generally consistent with the theoretical arguments of Chapter III. The raw product prices increase as coordination increases. The \$20.68 fully coordinated average price per ton of cane (P_y) is higher than in any other scenario. The coefficient of variation, intended to measure the variation of net returns among the members, was higher without quotas. This implies more inequality in the distribution of profits. Under a given payment scheme, higher degree of pricing accuracy did not mean higher profits or coordination. Note that with sugar-based payment, PAI increases from 0.903 to 0.967 when quotas are imposed but total profits, however, are lower. In summary, quotas can increase equity in payment and in the distribution of net returns at some possible efficiency loss. The coefficients of variation and price accuracy indices moved uni-directionally in a parallel fashion in all the scenarios. The magnitude of the difference between the performance of alternative payment schemes and the coordinated solution points out the importance of the internalization of the cooperative processing costs and revenues at the individual level.

Sensitivity Analysis

The preceding section has left questions regarding the sensitivity of performance to the structural parameters of the cooperative. In an attempt to solve this empirical question, selected scenarios are operationalized under alternative membership structures, variety selection and processing cost indices. Except for the coordinated cooperative case, the following scenarios are implemented only with the use of processing quotas. The model specifications are essentially the same as in the baseline results except in the parameters where change is specified.

Membership homogeneity

Members were homogenized by making them equally productive. That is, members' coefficients in Tables 4.4 and 4.5 are made equal to those of MAN_1. To ensure homogeneity, sugarcane fields are homogenized by setting all characteristics of a field that influence yields and costs equal to their sample averages (e.g. distance to the plant and age of cane). Other parameters remain the same. The performance results of the runs are presented in Table 5.2.

First note that myopia has an impact on the performance of the cooperative even if members are identical. The coordinated cooperative solution generated $4,566,406 in total net returns, while the myopic solutions generated $3,199,336 which represents a loss of $1,367,070 due to individualistic behavior of the members. The imposition of quotas did not affect total net returns but it does ensure equality in the distribution of net returns among the members including the case of a coordinated payment scheme. The solution without quotas did not affect the allocative efficiency of the cooperative (total net returns) yet it allows the possibility of benefiting some members at the expense of other members by affecting the distribution of net returns. In addition, those solutions without quotas with some pooled payment resulted in a decline in pricing accuracy indicating that some cross-subsidization occurred among the members. The removal of quotas allow for different distribution of net returns among the members with the same level of total net returns since members are identical. The results indicate that all members incurred the same level of costs and that they delivered the same varieties and grew cane with the same number of fields but the distribution of cooperative surplus and the schedule of deliveries

Table 5.2. Results of Performance Measures of Alternative Marketing Arrangements for Sugarcane Processing Cooperatives with Identical Members

Performance measure	Payment based on: Raw product		Finished product		Coordinated cooperative
	Quota	Nonquota	Quota	Nonquota	
Net returns					
Total	3,199,336	3,199,336	3,199,336	3,199,336	4,566,406
Member 1	639,867	676,587	639,867	725,458	1,002,908
Member 2	639,867	670,222	639,867	699,815	1,006,676
Member 3	639,867	632,555	639,867	614,903	939,197
Member 4	639,867	615,861	639,867	606,922	858,021
Member 5	639,867	604,311	639,867	552,238	759,603
C.V.	0.00	0.05	0.00	0.11	0.11
Pricing accuracy (PAI)	1.00	0.95	1.00	0.98	1.00
Raw product price ($/ton)	16.15[a]	16.15[a]	16.15	16.15	19.37
Sugar price ($/ton)	169.82	169.82	169.82[a]	169.82	210.63
Raw product (tons)	993,205	993,205	993,205	993,205	987,090
Sugar (tons)	94,480	94,480	94,480	94,480	94,790
Varieties	C	C	C	C	C
Acres of cane	25,600	75,600	75,600	75,600	24,000

[a]These are equilibrium prices in their respective payment arrangements. These "prices" satisfied equations (4.11) and (4.15) respectively. Thus the prices represent the average net revenue of the cooperative either in terms of tons of sugarcane or tons of sugar delivered.

were different when quotas were removed. The variation in net returns, therefore, is due to the allowance of favoristism in the time of deliveries for some members.

The results, in general, provide a favorable test of the internal validity of the model presented in Chapter III, which in most of the developments assume membership homogeneity. The coordinated cooperative solution not only provides higher level of total net returns, but it also provides the highest average price of raw product (P_y) and the smallest amount of raw product and even sugar.

Alternative Quality Choice Spectra

It is reasonable to expect that the selection of varieties of the sample used in the testing of the model has been in part affected by the structure of arrangement prevailing in the environment of sugarcane processing cooperatives where the sample was collected. Thus, those varieties possess values consistent with the objectives of the growers under those arrangements. However, when experimenting with alternative arrangements which have not occurred yet, one should consider the possibility of a somewhat different selection of sugarcane varieties. As an inquiry on the sensitivity of performance to the spectrum of quality-quantity choice possibilities, two major modifications are introduced and presented below.

The first part of the inquiry concerns the introduction of a high-tonnage low-sugar content variety. This is introduced as a substitute for variety D (in Table 4.6 or V_9 in Tables 4.4 and 4.5) that was excluded from the above solutions. Four changes are made. First, the PRS-intercept shifter (Table 4.4) is changed form -0.2 to -0.60.

Second, the intercept shifter for net tons per acre (Table 4.5) is increased from -2.61 to 3.39 (six tons increase). Third, its variable growing cost index is decreased (Table 4.6) from 1.1 to 0.8, making its growing cost $130 cheaper per acre planted and its processing cost index is reduced from 1.28 to 1.00 (Table 4.6). Fourth, for variety E, the PRS-intercept is increased by 0.80, its growing cost index decreased from 1.0 to 0.7 and the NT-intercept is decreased by two tons. The remaining parameters are the same as in the baseline run. The performance results with the modifications are presented in Table 5.3.

First note that the impact of coordination is magnified when the variation in quantity-quality choices increases. The coordinated cooperative generates $4,764,032 as total net returns. Payment based on sugar delivered with processing quotas ranked as second. Total net returns were $1,534,942 which represents a loss of $3,229,090 from the coordinated solution due to the individualistic behavior of the members. Payment based on the amount of raw product delivered with processing quotas resulted in $1,157,838 total net returns which corresponds to $3,606,194 foregone gains from the coordinated solution due to individualistic behavior of the members. These losses are greater than in the baseline results. The sugar-based payment loss increased by $885,608 and the cane-based payment loss increased by $1,216,836. The difference in total net returns between sugar-based and cane-based payments increased seven-fold to $377,104. Contrary to the baseline results, without exception each member is better off with sugar-based payment than with the cane-based payment. Dispersion in the distribution of profits (C.V.) is higher than in the baseline results and the degree of pricing accuracy diminishes for each payment system. Thus

Table 5.3. Results of Performance Measures of Alternative Marketing Arrangements for Sugarcane Processing Cooperatives with Alternative Specification of Raw Product Quality.

Performance measure	Payment based on: Raw product	Payment based on: Finished product	Coordinated cooperative
Net returns			
Total	1,157,838	1,534,942	4,764,032
Member 1	228,366	249,647	744,216
Member 2	98,366	216,686	859,082
Member 3	222,949	376,777	1,190,640
Member 4	13,872	28,146	394,489
Member 5	594,036	633,688	1,575,606
C.V.	0.96	0.77	0.47
Pricing accuracy (PAI)	0.935	0.956	1.0
Price (Py) ($/ton)	13.09[a]	13.51	20.01
Sugar price ($/ton)	143.49	147.81[a]	207.03
Raw product (tons)	891,383	921,927	1,002,033
Sugar (tons)	81,294	84,288	96,839
Varieties	D	E	E,C
Acres of cane	24,224	25,184	25,600

[a]These are equilibrium prices in their respective payment arrangements. These "prices" satisfied equations (4.11) and (4.15) respectively. Thus the prices represent the average net revenue of the cooperative either in terms of tons of sugarcane or tons of sugar delivered.

free riding is greater than in the baseline results. The relative variation in profits is the smallest for the coordinated case. Prices and the amount of raw and finished products were higher under sugar-based payment than in cane-based payment and were the highest for the coordinated payment system.

The second part of the analysis of sensitivity of performance to the quality-choice spectrum to which the grower is exposed deals with alternative processing cost indices. Two scenarios are presented. First is the case where processing cost indices are the same across varieties, thus implying no processing quality differentials. The processing index is set such that the coordinated solution yields approximately the same level of total net returns as in the baseline results. Second, the spread of the indices in Table 4.6 is made wider. The new indices are 0.9 and 1.0 for varieties A and B, and the indices of varieties C, D, and E are maintained at 1.28. The discussion below is limited to the case of processing quotas in cane-based and sugar-based payments. Table 5.4 shows the performance results with both fixed and spreaded processing cost indices.

In the case of less quality differential among the varieties, the impact of a coordinated payment scheme is of lesser magnitude. The coordinated cooperatives achieve total net returns of $4,646,334 for a single processing period, which is $1,675,646 more than with sugar-based payment and $1,736,529 more than with cane-based payment. The coefficients of variation of profits were lower than their counterparts in the baseline results. A greater degree of pricing accuracy was achieved in all cases. The amount of raw product, sugar and the sugar content in the cane were higher than in the baseline results. In general, the

Table 5.4. Results of Performance Measures of Alternative Marketing Arrangements for Sugarcane Processing Cooperatives with Alternative Processing Cost Indices

Performance measure	Payment based on: Raw product	Payment based on: Finished product	Coordinated cooperative	Payment based on: Raw product	Payment based on: Finished product	Coordinated cooperative
	Fixed processing cost indices			Spreading processing cost indices		
Net returns						
Total	2,909,805	2,970,688	4,646,334	3,216,261	3,321,260	5,439,848
Member 1	579,469	527,647	841,193	641,448	594,048	948,006
Member 2	402,835	472,363	821,588	460,067	538,374	100,642
Member 3	572,757	685,145	1,113,275	634,940	754,539	1,316,333
Member 4	275,046	215,043	427,601	328,095	287,804	524,588
Member 5	1,079,698	1,070,590	1,442,678	1,151,711	1,146,496	1,644,496
C.V.	0.52	0.53	0.41	0.49	0.48	0.39
Pricing accuracy (PAI)	0.951	0.969	1.0	0.952	0.971	1.0
Product price (Py) (\$/ton)	17.73[a]	17.80	20.09	18.07[a]	20.09	21.14
Sugar price (\$/ton)	182.51[a]	182.83[a]	206.22	186.21	186.82[a]	216.32
Raw product (tons)	917,194	919,142	988,227	918,473	918,923	992,644
Sugar (tons)	89,112	89,491	96,268	89,136	89,461	97,018

[a]These are equilibrium prices in their respective payment arrangements. These "prices" satisfied equations (4.11) and (4.15) respectively. Thus the prices represent the average net revenue of the cooperative either in terms of tons of sugarcane or tons of sugar delivered.

results were similar to the baseline results in terms of ranking of performance measures. However, the results suggest that as quality differentials among varieties disappear the impact of coordination on cooperative performance decreases.

With spread indices, the coordinated cooperative achieves total net returns of $5,439,848 which represents $2,118,588 more than the sugar-based payment, and $2,223,587 more than the cane-based payment. The net returns in all payment systems are higher than in the baseline results. Although the difference in total net returns between the coordinated solution and the myopic solution was a little less than in the baseline results, the difference between cane-based payment and sugar-based payment increase from $45,951 to $104,999, yet small difference when one considers their difference with the fully coordinated solution. There is also an increase in the amount of raw product, average price per ton of cane and amount of sugar produced. Though the the ranking of cost indices has been kept, a change in such ranking may bring somewhat different results.

Summary of Results

The main result of all the scenarios considered is that a coordinated cooperative increases its total net returns considerably when compared to a cooperative where the members try to individually maximize their own net returns. Furthermore, the outcome depends on the pricing rules and processing arrangements that underlie the operation of the cooperative. As members become more unequal or as the heterogeneity of the raw product potentially presents greater variation, the impact of coordination on coopertive performance is magnified.

In the baseline results of the sugarcane processing cooperative under study, sugar-based payment with processing quotas led to \$2,343,358 lower net returns than the coordinated cooperative. When members were paid based on tons of sugarcane delivered, the loss increased to \$2,389,358. These losses represent about one-half of net returns achievable in a coordinated way. Significant net returns losses also occurred even when members were made identical. Alternative runs with different membership and raw material quality parameters follow a pattern similar to that of the baseline results. In general, the results were consistent across scenarios simulated.

Processing quotas made the distribution of net returns more equal among the members and improved the pricing accuracy of the cooperative. The quotas, one could say, led to an improvement in equity but not necessarily to an improvement in allocative efficiency (total net returns). An important result is that quotas, when appropriately set, can induce coordination among members as in the case of cane-based payment in the baseline results. As members become more similar (equal), the impact of alternative marketing arrangements on the performance of the cooperative diminishes. Relative to the coordinated solution, however, the loss of net returns with individualistic behavior of the members is still significant. In short, the results provided a favorable test of the conceptual model presented in Chapter III. The results of the various models were comparable and each different analysis reinforced the results and conclusions derived form the other.

CHAPTER VI

CONCLUSION

Summary

The purpose of this research was to assess conceptually and empirically the impact of alternative marketing arrangements on the performance of processing cooperatives. The contributions of this study are, therefore, both theoretical and empirical.

The theoretical framework is provided by a model in which two types of behavior are discerned. The first type is individualistic or "myopic" behavior where members engage in strategic behavior motivated by individual rationality but produce an outcome that is collectively irrational. More specifically, it is shown that the prime incentive to behave myopically exists in the absence of binding agreements; therefore the maximum total net returns solution is unstable since a member in isolation benefits by adjusting his production if the marginal benefits of doing so exceed marginal costs. As all members move away from this Pareto optimal position, they collectively suffer impairment of net returns to establish "myopic equilibrium." With the second type of behavior, members are guided by collective rationality to achieve maximum net returns and a pareto optimal allocation of resources. Pricing policies, penalties (taxes), and quotas are suggested as instruments to avoid free riding and to ensure coordinated behavior. The model is extended to consider quality dimensions of the members' raw product and

the assumption of members' homogeneity is relaxed. The model allows analysis of a broader class of problems, in particular, free riding and the cooperative analogy of the prisoner's dilemma game.

The empirical procedures involved a mathematical programming model to test the conceptual framework. This model can be conceptually visualized as presenting two strata of decision making. At the first level, the pricing rules and the arrangements are set. At the second level members take production strategies in order to maximize their own net returns but regard policies set at the first level as given. The nested optimization simulates, then, the members' individualistic behavior. In all scenarios, the objective of the cooperative is to maximize the total level of net returns of the members. The structure of the objective, however, captures the arrangements that underlie the cooperative operation including payment arrangements. The model is applied to the case of sugarcane processing cooperatives in Florida. It is assumed that only three tools are available to the grower for his strategic behavior. These are variety of sugarcane, land cultivated, and time of delivery. Three payment policies are considered for analysis. These are payment based on the amount of cane delivered (complete pooling), payment based on the amount of sugar extracted from the deliveries, and a coordinated payment scheme. In addition, two types of processing arrangements, members' quotas and no quota, are considered. The result is an integer programming problem adapted to and solved as a network flow problem.

The empirical procedures generated results to assess the performance implications concerning the behavior of the members under alternative marketing arrangements and to explore the linkages of theoretical

framework with practical applications. The empirical analysis concerned two aspects of results. First and most important was the behavioral aspect, and second was the sensitivity of performance to membership and raw-product quality parameters. The coordinated cooperative increases its total net returns considerably, even with identical members, when compared to a cooperative where members try to maximize their own net returns in a strategic way. A sensitivity analysis showed that the impact performance of alternative marketing arrangements is intimately related to membership structure and quality specification of the raw material. The use of processing quotas increased coordination in some scenarios and in general made the distribution of profits more equal. The results of the various empirical model specifications were comparable and each reinforced the results derived from the other.

Conclusions

The conclusions of this research concern the theoretical analysis along with the empirical results. In general, the conclusions from the theoretical analysis were supported by the empirical results. The major distinction made between processing cooperatives and pure marketing cooperatives is the existence of a fixed cooperative plant. Even though individuals may choose to "cooperate" through the joint ownership and operation of the fixed plant, the possibility of "free riding" may result in inefficient utilization of the joint plant under alternative marketing arrangements.

An important conclusion of the theoretical analysis is that unpenalized strategic behavior of the members of a processing cooperative is likely to result in a sub-optimal operation of the cooperative plant.

This conclusion is supported by empirical results which also show that the outcome is sensitive to structural parameters of the cooperative and to alternative marketing arrangements. Individualistic behavior precludes the cooperative from attaining a maximum level of net returns and thus avoids a Pareto optimal allocation of resources. The use of pricing schemes and the proper use of processing quotas can inhibit such strategic behavior to induce a coordinated operation of the cooperative.

The increase in pricing accuracy, i.e., decrease in pooling of costs and returns generated by members' deliveries, does not necessarily lead to more inequity as consensus among cooperative scholars suggests. Based on the results of this study an increase in pricing accuracy can lead to greater individual net returns and to a less dispersed distribution of those returns. The use of processing quotas equalizes the distribution of net returns among members. The need for and the gains from coordination increase as the members become more heterogeneous and as the technological possibilities for strategic behavior are greater.

From a methodological standpoint, the problem can empirically be modeled as involving two strata of decision making: the setting of arrangements at the first level and the members' reaction at the second level. Even though the resultant model is large, it is manageable. The use of network flow algorithm, as used here, is encouraged as a solution method for a resultant integer programming problem. The structure of the empirical model used in this study can incorporate temporal and qualitative dimensions of the raw product and the fixed capacity problem that processing members face. The individualistic behavior of the members can be simulated with a subrouting that takes policies as

given. The use of network flow algorithms for the implementation of a resultant integer programming problem is encouraged.

As for the sugarcane processing cooperatives in Florida whose operations were described in Chapter IV, it is recommended that members be charged individually for the processing cost of their deliveries. Such a charge must be based on tonnage of cane delivered adjusted for the processing quality of the varieties. This measure is likely to enhance the performance of these cooperatives and to diminish free riding (cross-subsidization) among the members.

An overall conclusion of the conclusions is that a desirable solution to individualistic strategic behavior can be induced through marketing arrangements to enhance the performance of processing cooperatives. Examples are the use of quotas and individualized penalties and rewards embodied in payment policies. If the members' behavior is characterized by individualistic and not collective motives, then the remedy to achieve preferred performance outcome must be dealt with at the individual level at which the agents respond.

Limitations and Suggestions for Further Research

The scope of this study, as stated in Chapter I, was limited in the sense that no attempt was made to find the "best" or "optimal" marketing arrangements for processing cooperatives. The constraints that prevented the search for one optimal solution include lack of data and the involvement of value judgments. In the course of this study many problems were encountered that could not be dealt with adequately here but which merit further research.

One important limitation is that the solutions generated by the simulation of different structural arrangements do not entail either the cost of drafting or enforcing all conceivable contractual provisions. An alternative is to assume that these costs are constant. If such costs are greater than the gain in total net returns of implementing the coordinated cooperative operation, then a sub-coordinated solution is preferred and would constitute a second best solution. Another important limitation is that the cooperative objective of maximizing net returns, although it captures the arrangements and members' behavior, leads to a solution which implies that the bargaining of the members is based on their ability to maximize profits under those arrangements. For instance, when members' quotas are removed the solution would exclude, in part, deliveries of the relatively disadvantaged members under that payment system. Also, further work is needed on the theoretical model. The analysis of the impact of payment policies with regard to characteristics of the raw material needs to be strengthened. The theoretical framework also needs to incorporate spatio-temporal dimensions of the problem.

The empirical model and computer program can be utilized for other purposes beyond the scope of this study such as the benefit-cost of expanding the processing capacity of the cooperative plant or assisting in determining its size. The impact of an influx of members can also be assessed. The model can also be used to develop harvesting schedules for sugarcane or for other crops. The abstraction from risk considerations constitutes a serious limitation. For instance, in the case of sugarcane in Florida, freeze resistance and cold tolerance of varieties were ignored in this study, but certainly are not ignored by

the growers when they select what varieties to grow. The assumption that only variety, fields and time of delivery affect yields is restrictive.

Some limitations of a more methodological nature relate to the yield prediction equations. The low R^2 in the prediction equations indicates that a great deal of work is necessary to improve the performance of those equations. The development of prediction equations for each member and variety would be preferable.

Even though the model was internally consistent, its external consistency is jeopardized if maximization of net returns is of secondary importance to the members. If so, the interaction among the members under alternative arrangements would likely lead to different outcomes than those outlined here. The consideration of notions such as "profit-satisfiers" or of multiple individual and cooperative objectives may be appropriate. As a case in point, consider the work by Sheposh and Gallo (1973) who found in their experiments that the subjects were primarily concerned with relative outcomes. In particular, the subjects were concerned with not being surpassed by others rather than with the maximization of their own outcomes. In this regard, the use of game theory coupled with laboratory experiments of members' behavior would provide gains in understanding cooperative behavior and therefore in assessment of the performance impact of alternative marketing arrangements.

APPENDIX A

COOPERATIVE PLANT SIZE IN THE LONG RUN

This Appendix gives a symmetrical and consequently brief account of the implications of cooperative volume coordination in the long run. Its objective is to complement the short run counterpart presented in Chapter III.

Fixed Cooperative Plant Size in the Long Run

Over longer periods of time some fixed factors of production become variable and therefore some fixed costs also become variable. Those fixed factors play a role of shifting the position of the marginal cost of producing the raw material over a longer period of time. Let all the prices and the cooperative processing plant size be the same (see footnote 2, Chapter III) and that at least some members' fixed costs become variable in the time span considered. For instance, land could be rented, bought or sold to adjust production or be devoted to alternative uses.

Consider the case where output of each member corresponds to myopic equilibrium. Then, a cut in production level to adjust to the coordinated output would imply a reduction of the fixed inputs that become variable (in the long run) to achieve an optimal size in producing the coordinated output y^*. This implies an upward shift in the marginal cost curve as adjustment takes place. Further, the members' supply function (sum of individual marginal cost curves) would shift upward as more costs become variable. The new coordinated equilibrium would correspond to a new point where the new supply function intersects the marginal net revenue curve of the cooperative.

Figure A.1 displays the myopic equilibrium (point e), the short run coordinated equilibrium (point c), and the long run coordinated equilibrium (point d). LRS depicts the long run supply function (sum of long run marginal cost of the members). The benefits of coordination can be decomposed into two effects in the long run: (1) the benefits of coordination without fixed inputs adjustment (change in profits or

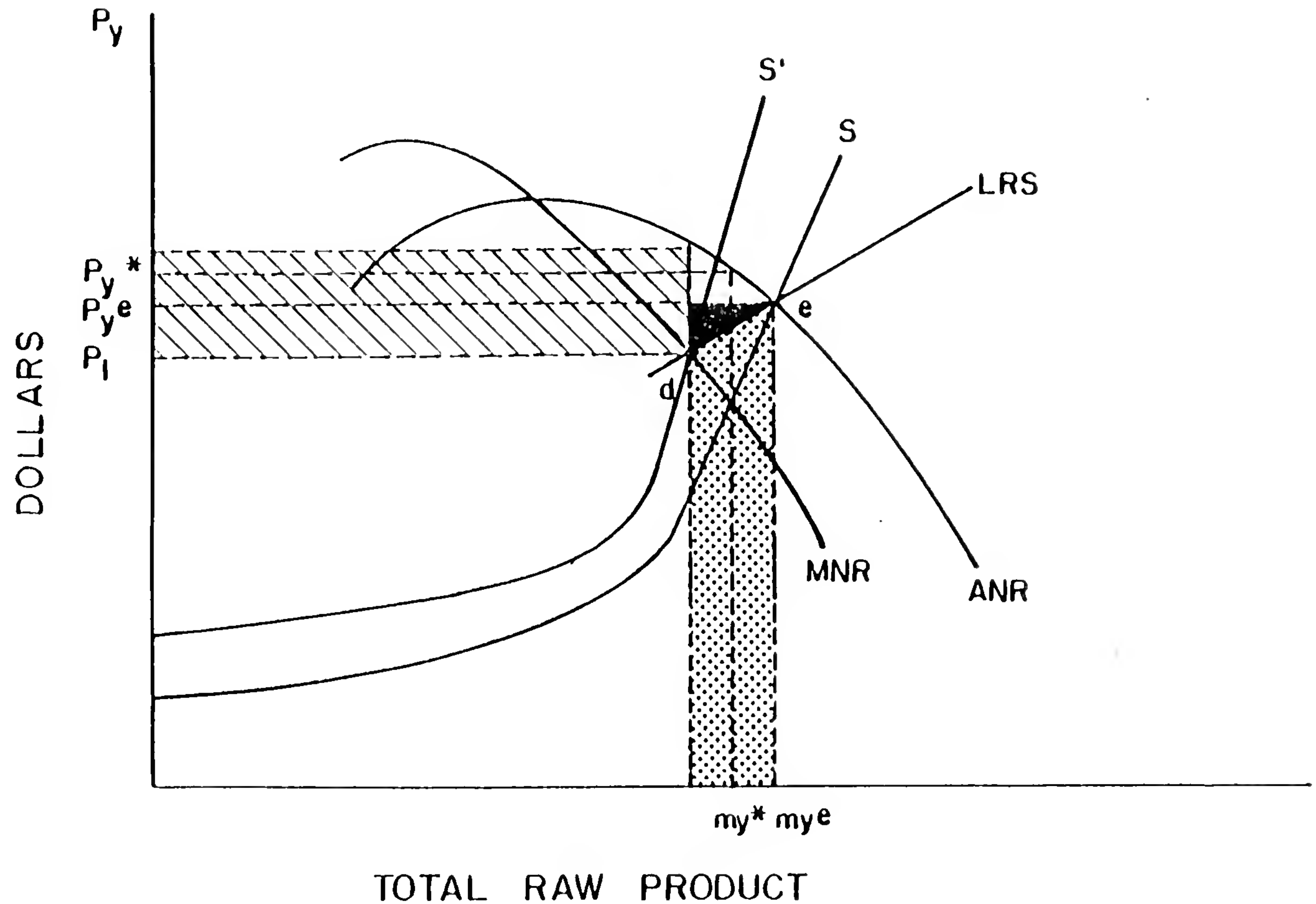

Figure A.1. Myopic and Coordinated Equilibria in the Long Run.

quasirents from e to c), and (2) the benefits (savings) from adjusting the fixed factors (from point c to point d).

Following Just et al. (1982) on welfare measurements over several periods, the pointed trapezoidal area represents the saving (cost) of adjustment. The correct measure of the total members' welfare impact, for a coordinated adjusted-period relative to a myopic equilibrium in Figure A.1 is the cross-hatched area minus the solid shaded area. The welfare gain is greater than in the short run (coordinated or myopic) since members can adjust fixed factors to attain the coordinated output with the optimal size of their operation (a movement toward the input expansion path).

Variable Cooperative Plant Size in the Long Run

In the preceding sections, the processing plant size is assumed fixed, together with fixed prices, and a unique cooperative average net revenue and marginal net revenue curves are identified. A fundamental detriment of the cooperative survival and performance, however, depends on whether or not the members' capital investment is adequate to sustain an efficient plant capacity. In the more conventional case, the cooperative long run cost function exhibiting a U-shape, an optimal plant size must be of finite capacity.

Let k be a continuous parameter that represents the amount of fixed input devoted to processing, and thus k measures the plant size or processing capacity. Fixed cooperative costs (FCC) is a monotonically increasing function of k. Paralleling the conventional long run cost analysis, for any arbitrary level of cooperative fixed input k, there is

a constrained cooperative total cost curve that is tangent to the unconstrained cost curve at that output where quantity of the fixed input is optimal, given input prices. For fixed P_z, the cooperative revenue curves are the mirror image of the processing cost curves.

Figure A.2 exhibits the long run average net revenue curve (LANR), long marginal net revenue curve (LMNR), and some corresponding short run curves (ANR_j, MNR_j, j=1,2,3). S is the long run supply of the current members with all inputs adjustable. To illustrate the nature of the problem, assume that the cooperative is initially operating with plant capacity k_1 and produces my^e in myopic equilibrium or my^c in coordinated equilibrium. The plant capacity is optimal in the processing of y_2 units of raw material. Cooperative quasi-rents and profits would increase by expanding capacity to k_2 and processing volume to my_2.

The investment needed to expand plant capacity must be weighted against the appropriately discounted future profits that accrue to the members from the capacity expansion. There is no _a priori_ reason for S to intersect the LANR curve at my_2. If S is to the left of that point, then membership influx or open market purchases could complement the expansion decision. The influx of new members would not only shift right the members' supply function, but also shift the cooperative average net revenue function through provision of capital that would increase the overall efficiency of the processing plant. If the cooperative plant size is k_3, beyond the optimal size k_2, plant size adjustment to k_2 could be brought about if some members exit, gradual disinvestment (reduction in k) occurs, till $k=k_2$, and supply of the members is S.

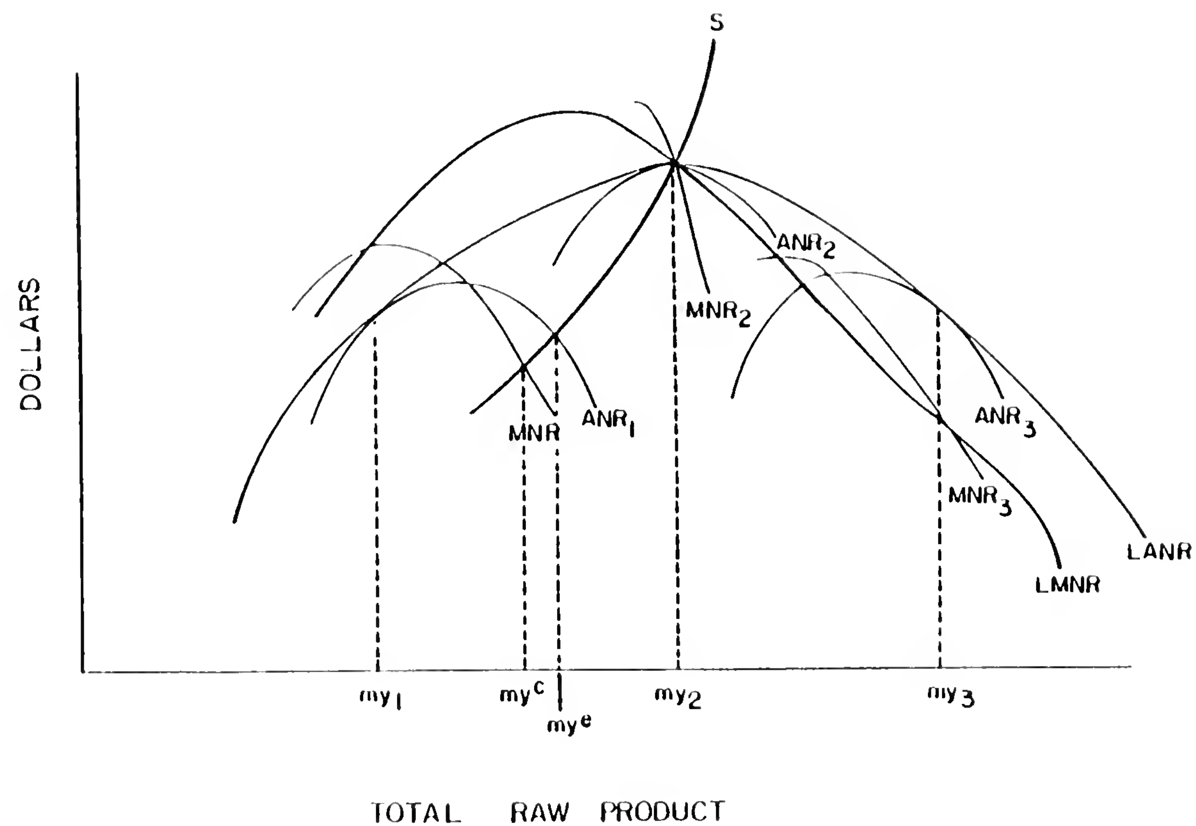

Figure A.2. Variable Cooperative Plant Size in the Long Run.

APPENDIX B

VARIABLES IN THE YIELD MODELS

The objective of this appendix is to assist understanding of the variables included in the specification of the models to predict sugar yields and cane tonnage. The following exposition is drawn from Alvarez et al. (1982) who developed a yield prediction model for Florida sugarcane.

Alvarez et al. (1982) developed a model to predict sugar and cane tonnage in Florida. Other methods such as direct visual appreciation to estimate tonnage and field chemical tests to estimate sugar content in the cane can be used. In actual applications of the empirical model the best predictors should be used; however, for availability and convenience it has been opted here to use statistical models. They identified a list of crucial factors that determine yields under Florida growing conditions. This list is presented in Table B.1 and selected items are discussed below.

Cane variety. Varieties not only differ in their ability to produce sugar and cane tonnage, but also in other ways discussed in Chapter IV such as processing quality.

Soil type: Different types of soils that prevail in the cane growing areas of Florida have different effects on the sucrose accumulation process, tonnage, or the ways in which the plant utilizes water and fertilizers. In this study, the types of soils from where the observations were collected had no significant effect on yields.

Fertilizers and chemicals: These factors obviously influence growth and the biological condition of the plant. Even though no data were available on these items, analysis of covariance (using members' class variables) may provide a proxy to estimate these effects.

Mode of harvest: Cane can be harvested either by hand or a number of mechanical processes. The latter may be detrimental to growth and sucrose accumulation of succeeding crops. Also, mechanical harvesting generally reduces the recoverability of sugar in the current crop.

Table B.1. List of Factors that Affect Sugarcane Growth and Sucrose Accumulations in Florida.[a]

Item factor	Disposition	
	Sugarcane growth	Sucrose accumulation
Cane variety	Include	Include
Soil type	Include	Include
Soil depth	Omit--A	Omit--A
Phosphorus	Omit--A	Omit--A
Potassium	Omit--A	Omit--A
Trace minerals	Omit--A	Omit--A
Lime	Omit--A	Omit--A
Pesticide	Omit--A	Omit--A
Herbicide	Omit--A	Omit--A
Cultivation practice	Omit--A	Omit--A
Water table management	Omit--A	Omit--A
Rainfall	Omit--B	Omit--B
Mode of harvesting	Include	Include
Skip planting	Omit--A	Omit--A
Distance from Lake Okeechobee	Include	Include
Year of crop cycle	Include	Include
Yield from previous crop	Include	Include
Period of harvest	Include	Include
Age of cane	Include	Include
Pest infestation	Omit--A	Omit--A
Disease	Omit--B	Omit--B
Freezes per year	Include	Include
Temperature	Include	Include
Solar radiation	Include	Include

[a]This refers to the disposition of the factors with respect to their inclusion in the model. In the omission code "A" denotes that data were not available for a particular factor and "B" denotes that the authors felt that the factor was not significant under Florida's conditions.

Source: Alvarez et al., 1982, p. 165.

Distance from Lake Okeechobee: The moderating influence of this lake on temperatures is one reason for expecting higher sugar and tonnage yields near the lake. Another reason is that soil depth generally decreases as one moves away from the lake which in turn affects yields adversely.

Year of crop cycle: Sugarcane is a multi-year crop. Alvarez et al. (1982) recognize that yield diminishes with successive ratoons. The typical cane life cycle in Florida is about three years. In the mathematical programming problem of this study, year of crop cycle is assumed to be equal to two--the sample average.

Period of harvest: This is particularly important for sucrose accumulation because of the time-dependent quality pattern of sugarcane.

Age of cane: Growth of cane accumulates over time. Thus, one can expect cane tonnage to increase with age.

Freezing temperatures: Frost damage is particularly detrimental to sugar yields. Even though the statistical models for predicting yields account for freezing temperatures, the mathematical model is non-stochastic and ignores the possibility of freezes.

Temperature: The average temperature is a prime factor involved in photosynthesis--the process which converts solar radiation to carbohydrates--which may be used either for growth or for sucrose accumulation.

While the above exposition is brief and only an auxiliary to the empirical procedures of this study, the reader further interested in the justification of the variables included in the yield prediction models is referred to Alvarez et al. (1982).

APPENDIX C

THE PROCESSING COOPERATIVE PROBLEM AS A NETWORK FLOW PROBLEM

The objective of this appendix is to illustrate the adaptation of the set of mathematical programming problems presented in Chapter IV to a minimum cost network flow framework. First it attempted this mathematically. Then a simple example is graphed and explained.

A network is a directed graph defined by a set of nodes, N, and a set of arcs, A, with ordered pairs of nodes (tail, head) as elements indexed by k. An arc is a path between two nodes. The arc that links node i and node j is said to have a head at i and a tail at j if the flow direction is from i to j. For each arc there is an objective contribution per unit of flow, C_k, a minimum allowable flow, ℓ_k, and a maximum allowable flow, V_k. Each node is either a supply node where units of flow enter the network, a demand node where units leave, or a transshipment node if the node only transfers the flow. Given this framework, the problem is to optimize the objective with flow X_k that satisfy the associated lower bound and capacities and preserve the conservation of flow at each node. Following Bradley et al. (1976), the problem can be stated as

Minimize

Objective $$\sum_{k \varepsilon A} C_k X_k \tag{C.1}$$

Subject to

Network structure $$\sum_{\substack{k \varepsilon A \\ \text{with tail} \\ i}} X_k - \sum_{\substack{k \varepsilon A \\ \text{with head} \\ i}} X_k = \underset{i \varepsilon N}{b_i} \tag{C.2}$$

Arcs bounds $$\ell_k \leq X_k \leq V_k \tag{C.3}$$

where

b_i = supply if i is a supply node,

= -demand if i is a demand node, or

= 0 if i is a transshipment node.

where X_k is the flow along arc k.. If one lets the fields be the goods that flow through the arcs of a network, the mathematical programming problems presented in Table 4.1, Chapter IV, can be solved as minimum cost network flow problems.

The objective in equation (C.1) is the network flow analogue of the cooperative objective in which at given arc k, C_k is the potential contribution to the objective by a field flow X_k.[1] Further, we can distinguish five types of arcs in such a problem:

1. One arc for each field (F in total) to initiate the flow. Each of these arcs has an upper bound of one ($V_k = 1$) and a lower bound of zero ($\ell_k = 0$).

2. Arcs determine when each field is harvested and with what variety. With T time periods there are T x F of these arcs. Because varieties are endogenous a preoptimization is performed to assign varieties to fields on a processing period basis. Figure C.1 illustrates the varieties assignment.

3. One arc for each processing period (T total) to impose the mill capacity constraints (upper and lower bounds for these arcs).

4. One arc for each member-period combination to impose the members' quotas. With m members, there are m x T of such arcs.

5. An arc from sink to source, a dummy arc.

Since the decision to harvest a field in a particular period is a (0,1) integer variable and the parameters (bounds and costs) are

---

[1]X_k here is equivalent to F_{pft} in Chapter IV. Furthermore, the problem presented in Table 4.1 can be written in the same form as equations (C.1) through (C.3) if one lets the right hand sides (arc bounds) for mill capacity and members' quotas be expressed in field units rather than tonnage.

Figure C.1. A Two-Stage Assignment of Varieties.

Varieties differ by

1. Net tons of cane produced per acre
2. Sugar content
3. Time to process
4. Growing cost

All other factors can be computed from these four.

↓ Varieties are assigned to fields in a processing period basis

Fields differ by

1. Management
2. Weather
3. Varieties

↓ Fields are assigned to periods

Limited processing capacity and other processing arrangements.

integers, the network flow solution is guaranteed to be integer. In this sense, the technique is equivalent to integer linear programming.

There are two types of manipulations that allow the simulation of the cooperative arrangements: the manipulation of arc capacities (sets 1, 3, 4 above) and the manipulation of arc returns (set 2 above). The manipulation of the first set of arcs allows for volume of raw material (sugarcane) adjustments via field adjustments (setting $\ell_k = 0$). That is, a hypothetical situation results where the cooperative does not have to process all the cane of the candidate fields. The manipulation of the second set of arcs allows the simulation of different cooperative objectives by evaluating each arc according to the corresponding member maximand. With endogenous variety choice, a preoptimization is performed where the variety yielding the highest return for each period is selected according to the member maximand (Figure C.1). The manipulation of the third set of arcs provides a methodology to evaluate the effect of alternative processing quotas by changing the pertinent upper and lower bounds. The manipulation of the capacity of the fourth set of arcs is useful to determine the benefit-cost of expanding processing capacity and determining the optimal size of the processing plant. Those issues, however, are beyond the scope of this study.

Mill capacity and members' quotas are defined in terms of number of fields rather than tonnage. A heuristic feasible solution can be obtained by readjusting the processing parameters (number of fields) of the fourth set of arcs so that the processing load in each period is insured to be within actual tonnage bounds. In addition, the solution must satisfy cooperative myopic equilibrium in some scenarios, which is imposed through batch iterations with the program of Appendix D. Thus,

an iterative procedure was applied to solve the problem under various scenarios.

For simplicity, consider a cooperative with two members. Each member has two fields and the raw material values differ along three periods of the processing season. In each period there are lower and upper bounds (quotas) for the members and the cooperative processing plant. Assume that the payoff matrix and constraints are as depicted in Table C.1. The network flow problem is illustrated graphically in Figure C.2.

Let N_i (i=0, ..., 14) denote the set of nodes (in circles in Figure C.2) and X_{ij} the arc confined between nodes N_i and N_j. The problem is that of maximizing some objective (minimizing its negative value) of sending a flow (fields) from a source node (N_0) to a sink node (N_{14}), while satisfying the arc capacities between them. Each arc contains in parentheses its lower bound, upper bound, and the return to that arc (ℓ_k, V_k, C_k). The first set are the generic (fields) arcs. The following 12 arcs (X_{ij}, i=1, ..., 4; j=5, ..., 10) are the arcs whose values give the return for each field in each of the three periods, giving C_k of equation C.1. These evaluations are assigned from the payoff matrix (Table C.1) and varieties are assigned as illustrated in Figure C.1. The next six arcs (X_j, i=1, ..., 10; j=11, ..., 13) are the arcs that bound each member to deliver according to his quotas. The next three arcs impose the processing capacity ($X_{i,14}$, i=11, ..., 13) per processing period. The last arc (from sink to source) is a dummy arc ($X_{14,0}$).

The program used to solve the problem of Chapter IV as a minimum cost network flow is presented in Appendix D. Those readers further interested in network flow analysis are referred to Hillier and Lieberman (1980), and for more detailed work to Hu (1969).

Table C.1. Payoff and Bounds for the Hypothetical Network Flow Example.

Payoff:

Grower	Field	Returns in periods 1	2	3
1	1	4	5	6
	2	3	5	8
2	3	2	4	6
	4	4	5	5

Bounds:

Grower	Bounds per period Lower	Upper
1	0	1
2	0	1
Mill	0	2

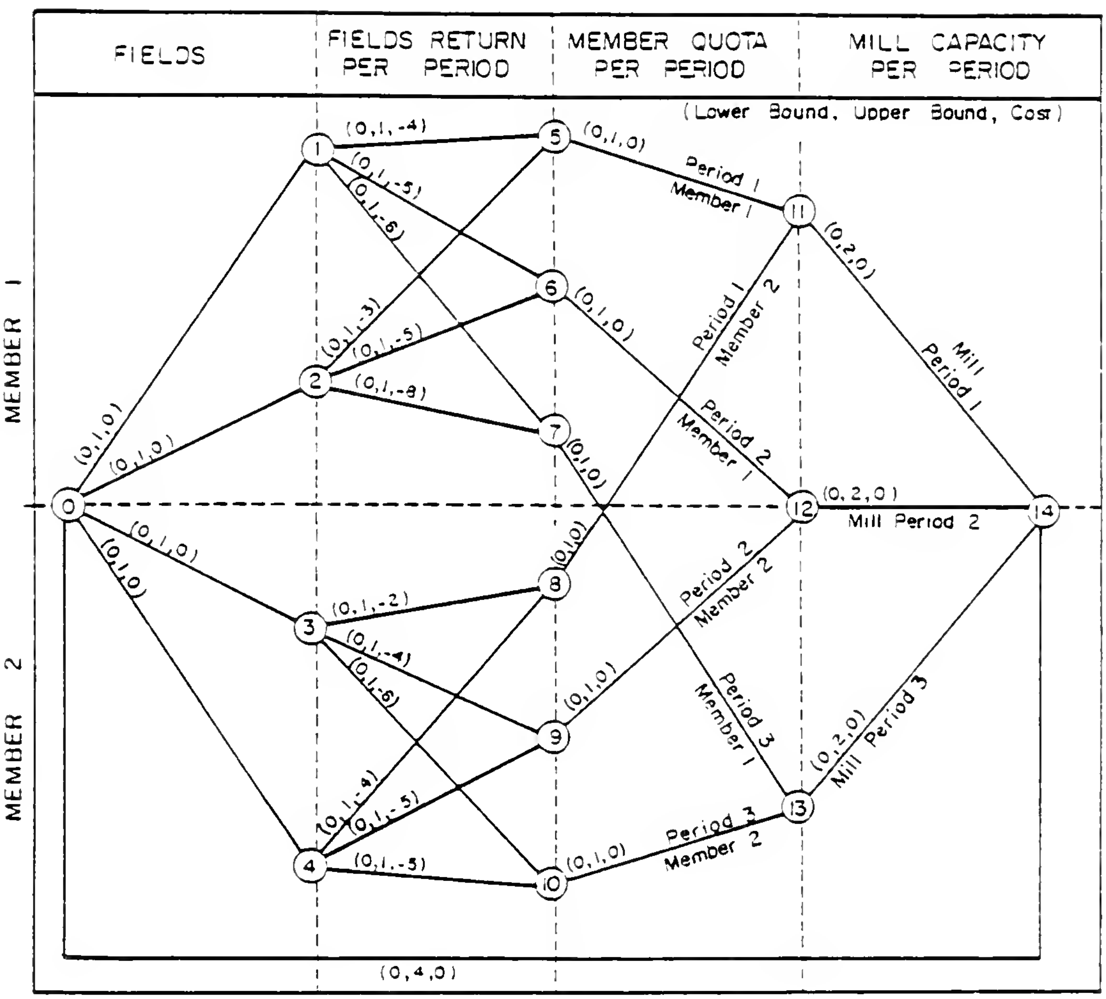

Figure B.2. Network of the Example Problem.

APPENDIX D

THE COMPUTER PROGRAM

This appendix presents the computer program used to obtain the baseline results. The program can be broken down in three parts. In the main program, pricing rules and processing arrangements are set. The function COST performs an optimization over varieties of cane according to the objective set in the main program. The subroutine OPT optimizes over all members according to the options set at the main program and to the results of the COST function. The optimization code (OPT), which solve the network flow problem with an out-of-kilter code, was wrote and made available by professor Thom Hodgson of the Industrial and Systems Engineering Department at the University of Florida. Computing time was provided at no charge by the VAX system of the Institute of Food and Agricultural Sciences of the University of Florida. The program used about 27 minutes of computing time (C.P.U.) for a typical run.

```
C THIS PROGRAM USES FIELDS AS INPUT OF MILL CAPACITY
C*****************************************************************************
C* NETWORK FOR SUGAR CANE HARVEST AND  COOPERATIVE SYSTEM SIMULATION
C*
C* NFLDS=FIELD INFORMATION
C*        COLUMN 1 = VARIETY NUMBER
C*        COLUMN 2 = YEAR OF CROP CYCLE
C*        COLUMN 3 = AERIAL MILES FROM LAKE OKEECHOBEE
C*        COLUMN 4 = MEMBER NUMBER
C*        COLUMN 5 = ALTERNATIVE MEMBERSHIP STRUCTURE
C*        COLUMN 6 = AGE OF CANE 2 WEEK PERIODS
C*        COLUMN 7 = LAST YEAR PERCENT OF RECOVERABLE SUGAR
C*        COLUMN 8 = LAST YEAR NET TONS PER ACRE
C*        COLUMN 9 = FIELD ACRES.
C*        COLUMN 10= AERIAL MILES FROM THE FIELD TO THE MILL
C*
C* NPLAN = MEMBERS INFORMATION
C*          COLUMN 1 = MEMBER NUMBER
C*          COLUMN 2 = LOWER QUOTA PER PERIOD IN FIELDS NUMBER
C*          COLUMN 3 = UPPER QUOTA PER PERIOD IN FIELDS NUMBER
C*
C* N(I) = VARIETY OF FIELD I
C* N2   = SOME ARCH NUMBER
C* N6   = PERIOD NUMBER
C* COST = OBJECTIVE TO BE OPTIMIZED
C* NF=TOTAL NUMBER  OF FIELDS
C* NP=TOTAL NUMBER OF GROWERS
C* NEXT=HARVEST PERIOD TO START WITH
C* N1   = ACTUAL NO. OF HARVEST PERIODS USED (NPER-NEXT+1)
C* FLDTON(I) I= TONS OF RAW CANE PER FIELD; FROM FUNC. COST
C* MILCAP      = MILL CAPACITY IN TONS
C* MILFLD(I,J) I= LOWER BOUNDS ON FIELDS PER HARVEST PERIOD FOR MILL
C*              J= UPPER BOUND ON NO. OF FIELDS PER HARVEST PERIOD
C* NPER=TOTAL NUMBER OF HARVEST PERIODS
C* NMHI=UPPER BOUND ON MILL CAPACITY IN NUMBER OF FIELDS
C* NMLO=LOWER BOUND ON MILL CAPACITY IN NUMBER OF FIELDS
C* NPL=TOTAL NUMBER VARIETIES CONSIDERED
C* NAMFLD=CONTAINS FIELD NAMES
C* NPLNT=CONTAINS IDENTIFICATION NAMES
C* NWKS=CONTAINS HARVEST PERIOD NUMBER AND CALENDAR DATE
C*
C* NWEATHER = WEATHER INFORMATION
C*            COLUMN 1 = AVERAGE DEGREE DAYS (TEMPERATURE)
C*            COLUMN 2 = PREVIOUS YEAR AVERAGE DEGREE DAYS (COL 1)
C*            COLUMN 3 = AVERAGE MONTHLY SOLAR RADIATION IN LANGLEY UNITS
C*            COLUMN 4 = PREVIOUS YEAR AVERAGE MONTHLY RAD (COL 3)
C*            COLUMN 5 = ACCUMULATED "DEGREE FREEZE" PREVIOUS TO HARVEST
C*            COLUMN 6 = NUMBER OF DAYS SINCE LAST FREEZE IN CURRENT SEASON
C*            COLUMN 7 = I, WHERE I=1 FOR 1971 AND I=K+1 FOR THE KTH YEAR AFTER
C*
C* SUR(ARCS)  SURPLUS PER FIELD BEING KEPT TRACK OF
C* GCOST(ARCS)GROWERS COST PER FIELD
C* GINFO(I,J)  I=1,NP  NUMBER OF PRODUCERS
C*             J=   1  TONS OF SUGAR PER PRODUCER
C*                  2  TOTAL TONS OF CANE PER PRODUCER
C*                  3  TOTAL SURPLUS PER GROWER
C*                  4  TOTAL COST    PER GROWER
C* TPERGP(I,J)  TONS PER GROWER PER PERIOD
C*             I=1,NP  NO. OF PRODUCERS
C*             J=1,N1  NO. OF ACTUAL HARVEST PERIODS
C* NFOPH (I,J)  NUMBER OF FIELDS HARVESTED PER GROWER PER PERIOD
C* TLOAD (N1)   TONS SUMMED FOR EACH PERIOD OF HARVEST
C*
C* NOTE-ALL OTHER VARIABLES DEFINED IN SUBROUTINES
```

```
C*******************************************************************
      COMMON NPLAN(10,10),NI(5000),NJ(5000),NCOST(5000),NFLD(5000),PRI,
     CNWKS(5),NA(950),NB(950),N(800),NFLDS(10),GINFO(10,4),
     CNOPT(4),NPI(950),NLO(5000),NHI(5000),NBF(5),TLOAD(5),
     CNICA(5),MILFLD(800,5,5),FLDTON(5000),NWEATHER(7),TPERGP(10,5),
     CGCOST(5000),SUR(5000),NOWN(5000),AVET(5),NFOPH(10,5),NZ(5000),
     CSHARE(5),NMHI(5),NMLO(5)
      CHARACTER*1 NPLNT(5)
C
C
      READ(5,501)NF,NP,NEXT,NPER,MILCAP,NPL
 501  FORMAT(4I4,I6,I4)
      NP1= NP+1
      NF1= NF+1
      N1=NPER-NEXT+1
      PRINT *,'ENTER MILL UPPER CAPACITY FOR 5 PERIODS (FIELD UNITS)'
      READ *,(NMHI(I),I=1,5)
      PRINT *,'ENTER MILL LOWER CAPACITY FOR 5 PERIODS (FIELD UNITS)'
      READ *,(NMLO(I),I=1,5)
      READ(5,503)(NWEATHER(I),I=1,7)
 503  FORMAT(10I4)
      READ(5,504)(AVET(I),I=1,N1)
 504  FORMAT(5F6.2)
      READ(5,503)((NPLAN(I,J),J=1,10),I=1,NP)
      NODES=2+NF+N1*NP1
      NARCS=NF1+(NF+NP1)*N1
C*******************************************************************
C     PROGRAM OPTIONS
C*******************************************************************
      PRINT *,'ENTER 0 IF FIELDS CHOICE,  1 OTHERWISE'
      READ *,NOPT(1)
      PRINT *,'ENTER 1 IF VARIETY CHOICE, 0 OTHERWISE'
      READ *,NOPT(2)
      PRINT *,'ENTER 1 IF MEMBERS QUOTA,  0 OTHERWISE'
      READ *,NOPT(3)
      PRINT *,'OBJECTIVE:  1 TONNAGE PRICING, 2 SUGAR PRICING,
     C 3 COORDINATED,4 MAX TONNAGE,5 MAX SUGAR'
      READ *,NOPT(4)
      IF (NOPT(4).GT.2) GO TO 506
      PRINT *,'ENTER PRICE'
      READ *,PRI
 506  CONTINUE
      DO 5 I=1,NF
      READ(5,507) (NFLDS(J),J=1,10)
 507  FORMAT(16X,6I3,3I5,I4)
      IF (NFLDS(1).EQ.7) NFLDS(1)=3
      IF (NFLDS(1).EQ.9) NFLDS(1)=4
      IF (NFLDS(1).EQ.8) NFLDS(1)=5
      N(I)=NFLDS(1)
C*******************************************************************
C* ARCS TO INSURE EACH FIELD IS HARVESTED (ONCE)
C*******************************************************************
      NI(I)=1
      NJ(I)=I+1
      NCOST(I)=0
      NHI(I)=1
      NLO(I)=NOPT(1)
      NFLD(I)=0
C*******************************************************************
C* ARCS THAT IDENTIFY FIELDS WITH HARVEST PERIODS
C*******************************************************************
      N5=NFLDS(4)
      DO 5 J=1,N1
```

```
      N2=NF+J+(I-1)*N1
      NI(N2)=I+1
      NOWN(N2)=N5
      NJ(N2)=NF1+J+(N5-1)*N1
      NHI(N2)=1
      NLO(N2)=0
      NFLO(N2)=0
      N6=J+NEXT-1
      NCOST(N2)=COST(NFLDS,NWEATHER,NOPT,N6,PRI,NVAR,TON,GC,SURF,Z)
      SUR    (N2)= SURP
      GCOST  (N2)= GC
      NZ     (N2)= Z
      N(I)=NVAR
 5    FLDTON(N2)= TON
C*********************************************************************
C* ARCS WITH MEMBERS PROCESSING QUOTAS IN NUMBER OF FIELDS
C*********************************************************************
      NPN1= NP*N1
      NFN1= NF*N1
      DO 7 I=1,NP
      DO 7 J=1,N1
      II= J+(I-1)*N1
      N2=NF+NFN1+II
      NI(N2)=NF1+II
      NJ(N2)=NF1+NPN1+J
      NCOST(N2)=0
      NHI(N2)=NPLAN(I,J+5) + (1-nopt(3))*999
      NLO(N2)=(NPLAN(I,J))*NOPT(3)
 7    NFLO(N2)=0
C*********************************************************************
C* ARCS WITH MILL CAPACITY CONSTRAINTS IN NUMBER OF FIELDS
C*********************************************************************
      DO 8 I=1,N1
      N2=NF+NFN1+NPN1+I
      NI(N2)=NF1+NPN1+I
      NJ(N2)=NODES
      NCOST(N2)=0
      NHI(N2)=NMHI(I)
      NLO(N2)=NMLO(I)
8     NFLO(N2)=0
C*********************************************************************
C* ARC FROM SINK TO SOURCE, A DUMMY ARC
C*********************************************************************
      NI(NARCS)=NODES
      NJ(NARCS)=1
      NCOST(NARCS)=0
      NHI(NARCS)=NF
      NLO(NARCS)=0
      NFLO(NARCS)=0
      CALL OPT(NODES,NARCS,NI,NJ,NHI,NLO,NCOST,NFLO,NPI,NA,NB,NFEAS)
C*********************************************************************
C* READING OF PERIODS AND VARIETIES IN ENGLISH
C*********************************************************************
      DO 9 I=1,NPL
      NWKS(I)=I
 9    READ(5,509)NPLNT(I)
 509  FORMAT(2X,A1)
      NTOTAL=0
C      WRITE(6,601)
 601  FORMAT(1H1,'  FIELD  VARIETY  PERIOD  OBJECTIVE'/3X,'NO. ',21X,
     C'VALUE'/3X,5(1H-),2X,7(1H-),2X,6(1H-),2X,9(1H-))
C*********************************************************************
C* DETERMINE WHEN FIELD IS TO BE HARVESTED BY COUNTING ARCS
```

```
C**********************************************************************
      DO 15 I=1,NF
      K=NEXT-1
      DO 13 J=1,N1
      K=K+1
      N2=NF+J+(I-1)*N1
      IF(NFLO(N2).EQ.1) GO TO 14
 13   CONTINUE
      GO TO 15
 14   NCOST(N2)=-NCOST(N2)
      NTOTAL = NTOTAL + NCOST(N2)
      GINFO(NOWN(N2),1)= GINFO(NOWN(N2),1)+NZ(N2)
      GINFO(NOWN(N2),3)= GINFO(NOWN(N2),3)+SUR  (N2)
      GINFO(NOWN(N2),4)= GINFO(NOWN(N2),4)+GCOST(N2)
      GINFO(NOWN(N2),2)= GINFO(NOWN(N2),2)+FLDTON(N2)
      DO 10 KK=1,5
 10   IF (N(I).EQ.KK) NICA(KK)= NICA(KK) + 1 ! TO COUNT VARIETIES
      NBF(J)=NBF(J)+1
      TLOAD(J)=TLOAD(J)+FLDTON(N2)
      NFOPH(NOWN(N2),J)= NFOPH(NOWN(N2),J) +1
      TPERGP(NOWN(N2),J)= TPERGP(NOWN(N2),J) + FLDTON(N2)
c      WRITE(6,603)I, NPLNT(N(I)),NWKS(K),NCOST(N2)
 603  FORMAT(4X,I3,6X,A1,7X,I1,3X,I9)
 15   CONTINUE
C**********************************************************************
C*    PRINT TABLE OF PROGRAM OPTIONS SELECTED
C**********************************************************************
      WRITE(6,640)
      IF (NOPT(1).GE.1) WRITE(6,641)
      IF (NOPT(1).LE.0) WRITE(6,642)
      IF (NOPT(2).GE.1) WRITE(6,643)
      IF (NOPT(2).LE.0) WRITE(6,644)
      IF (NOPT(3).GE.1) WRITE(6,645)
      IF (NOPT(3).LE.0) WRITE(6,646)
      IF (NOPT(4).LE.1) WRITE(6,647) PRI
      IF (NOPT(4).EQ.2) WRITE(6,648) PRI
      IF (NOPT(4).EQ.3) WRITE(6,649)
      IF (NOPT(4).EQ.4) WRITE(6,650)
      IF (NOPT(4).GE.5) WRITE(6,651)
C
 640  FORMAT(1H1,6X,'TABLE OF PRINT OPTIONS'//)
 641  FORMAT(3X,'NOPT(1) = 1      ALL FIELDS WITH MULTIPLE HARVEST'//)
 642  FORMAT(3X,'NOPT(1) = 0      PROGRAM CHOOSES WHICH FIELDS TO ',
     C'HARVEST BASED ON OBJECTIVE CHOICE'//)
 643  FORMAT(3X,'NOPT(2) = 1      PROGRAM CHOOSES VARIETY'//)
 644  FORMAT(3X,'NOPT(2) = 0      VARIETY CHOICE PREDETERMINED'//)
 645  FORMAT(3X,'NOPT(3) = 1      MEMBERS HAVE TONNAGE QUOTA BY ',
     C'PERIOD'//)
 646  FORMAT(3X,'NOPT(3) = 0      MEMBERS HAVE NO QUOTA (TONS)'//)
 647  FORMAT(3X,'NOPT(4) = 1      OBJECTIVE IS TONNAGE PRICING',F7.2//)
 648  FORMAT(3X,'NOPT(4) = 2      OBJECTIVE IS SUGAR PRICING',F7.2//)
 649  FORMAT(3X,'NOPT(4) = 3      OBJECTIVE IS MAXIMIZE TOTAL ',
     C'PROFITS'//)
 650  FORMAT(3X,'NOPT(4) = 4      OBJECTIVE IS MAXIMIZE TONS OF CANE'//)
 651  FORMAT(3X,'NOPT(4) = 5      OBJECTIVE IS MAXIMIZE TONS OF SUGAR'//)
C**********************************************************************
C*    TOTAL ITEMS FOR GROWER INFORMATION TABLE
C**********************************************************************
      TZ=0
      DO 17 I=1,NP
      TZ    = TZ    + GINFO(I,1)    !TOTAL TONS OF SUGAR
      TSUR  = TSUR  + GINFO(I,3)    !TOTAL SURPLUS FOR ALL PRODUCERS
      TCOST = TCOST + GINFO(I,4)    !TOTAL COST    FOR ALL PRODUCERS
```

```
 17    TCANE = TCANE + GINFO(I,2)    !TOTAL TONS OF CANE
       FCC=8620000
       TSUR = TSUR - FCC
       DO 604 I=1,5
       SHARE(I) = GINFO(I,2)/TCANE
       GINFO(I,3) = GINFO(I,3) - SHARE(I)*FCC
 604   PRINT *, 'NET SURPLUS OF MEMBER I IS',GINFO(I,3)
       WRITE(6,605) NTOTAL
 605   FORMAT(/53X,' THE TOTAL EXPECTED OBJECTIVE VALUE =',I10)
       IF(NFEAS.EQ.0) WRITE(6,606)
 606   FORMAT( ' INFEASIBLE SOLUTION ')
C
C***    WRITE GROWERS INFORMATION TABLE
C

       P1=TSUR/TCANE
       P2= TSUR/TZ
       WRITE(6,614)
       DO 18 I=1,NP
       IF(NOPT(4).LE.1 .OR.  NOPT(4).EQ.4) PAY=P1* GINFO(I,2)
       IF(NOPT(4).EQ.2 .OR.  NOPT(4).GE.5) PAY=P2* GINFO(I,1)
       IF(NOPT(4).EQ.3)                    PAY=GINFO(I,3)
       PROF=  PAY   - GINFO(I,4)
       TPROF= TPROF+ PROF
       TPAY = TPAY + PAY
       PAI  = (GINFO(I,3)- ABS(GINFO(I,3)-PAY))/GINFO(I,3)
       TPAI = TPAI + GINFO(I,2)/TCANE*PAI
 18    WRITE(6,616) I,(GINFO(I,J),J=1,4),PAY,PROF,PAI
       WRITE(6,618) TZ,TCANE,TSUR,TCOST,TPAY,TPROF,TPAI
       WRITE(6,620)
       WRITE(6,658) P1,P2
       DO 660 KK=1,5
 660   WRITE(6,659)KK,NICA(KK)
       IF(NOPT(4).LE.1)WRITE(6,656)
       IF(NOPT(4).EQ.2)WRITE(6,657)
       IF(NOPT(4).EQ.3)WRITE(6,655)
       IF(NOPT(4).EQ.4)WRITE(6,656)
       IF(NOPT(4).GE.5)WRITE(6,657)
C
 614   FORMAT(////18X,'GROWERS INFORMATION TABLE'///11X,6(1H-),
      2'TONS',5(1H-)/
      3' NUMBER    SUGAR      CANE      SURPLUS        COST      PAYMENT',
      3'   PROFIT   PAI'/
      41X,6(1H-),4X,5(1H-),2X,8(1H-),3(3X,9(1H-)),3X,6(1H-),2X,4(1H-))
 616   FORMAT(3X,I2,1X,2F10.0,3F12.0,F9.0,F6.3)
 618   FORMAT(1X,78(1H=)/1X,'TOTALS',F8.0,F11.0,3F12.0,F9.0,F6.3)
 620   FORMAT(////' NOTE:')
 653   FORMAT(5X,'PAYMENT BASED ON TONNAGE PRICE INPUT IN OPTION 1')
 654   FORMAT(5X,'PAYMENT BASED ON SUGAR   PRICE INPUT IN OPTION 2')
 655   FORMAT(5X,'PAYMENT SET EQUAL TO TOTAL GROWER SURPLUS')
 656   FORMAT(5X,'PAYMENT BASED ON PRICE = TOTAL SURPLUS / TOTAL TONS')
 657   FORMAT(5X,'PAYMENT BASED ON PRICE = TOTAL SURPLUS / TOTAL SUGAR')
 658   FORMAT(///5X,'P1= TOTAL SURPLUS / TOTAL TONS OF CANE',F7.2/
      C5X,'P2= TOTAL SURPLUS / TOTAL TONS OF SUGAR',F6.2)
 659   FORMAT(//' NUMBER OF EACH VARIETY'/ 5(20X,I3,I7))
C
C *** COMPARED TO MILL CAPACITY
       WRITE(6,607)
C
       DO 19 L=1,N1
       AVE= 32.*AVET(L)
       IF (NBF(L).GE.1)AVE= TLOAD(L)/NBF(L)
       FDMIN=MILCAP*0.8
```

```
      FDMAX=MILCAP*1.0
      AT= TLOAD(L)/NBF(L)
      FMIN= FDMIN/AT
      FMAX= FDMAX/AT
      WRITE(6,608)L,NMLO(L),NBF(L),NMHI(L),FDMIN,TLOAD(L),FDMAX,
     CFMIN,FMAX,AT
 19   CONTINUE
C
 607  FORMAT(1H1,17X,18(1H-),' MILL CONSTRAINTS ',18(1H-)/6X,'HARVEST',
     +5X,5(1H-),' FIELDS ',5(1H-),5X,11(1H-),' TONNAGE ',11(1H-)/6X,
     +'PERIOD',6X,'MIN   ACTUAL   MAX      MIN(.8)      ACTUAL      MAX',
     A'(1.0)',10X,'MIN    MAX    AVETON'/
     +/6X,7(1H-),5X,3(1H-),3X,6(1H-),3X,3(1H-),5X,7(1H-),5X,
     +6(1H-),5X,8(1H-),7X,2(3X,3(1H-)),3X,6(1H-))
 608  FORMAT(9X,I2,3X,2I7,I8,F12.0,F11.0,F12.0,9X,2F6.0,3X,F6.1)
C
C***  GROWER INFORMATION TABLE IN FIELDS AND TONNAGE
C
      DO 21 I=1,NP
      WRITE(6,610) I
      DO 21 J=1,N1
      AVE= 32.*AVET(J)
      IF(NFOPH(I,J).GT.0)AVE= TPERGP(I,J)/NFOPH(I,J)
      LO   = AVE* NPLAN(I,J)
      IACT= AVE* NFOPH(I,J)
      IHI  = AVE* NPLAN(I,J+5)
 21   WRITE(6,609) J,NPLAN(I,J),NFOPH(I,J),NPLAN(I,J+5),LO,
     +IACT,IHI
 609  FORMAT(1X,2(6X,I4),3X,I4,4X,I4,6X,I6,5X,I6,7X,I6)
 610  FORMAT(////1H0,17X,13(1H-),' GROWER NO. ',I3,' CONSTRAINTS ',
     +14(1H-)/6X,'HARVEST',5X,5(1H-),' FIELDS ',5(1H-),5X,11(1H-),' TONN
     +AGE ',11(1H-)/6X,'PERIOD',6X,'MIN   ACTUAL   MAX        MIN      ',
     +' ACTUAL         MAX'/6X,7(1H-),5X,3(1H-),3X,6(1H-),3X,3(1H-),5X,
     +7(1H-),5X,6(1H-),5X,8(1H-))
      STOP
      END
C*********************************************************************
      FUNCTION COST(NFLDS,NWEATHER,NOPT,N6,PRI,NVAR,TON,GC,SURP,Z)
C*********************************************************************
C* PRS=EXPECTED PER CENT OF RECOVERABLE SUCROSE
C* TON=EXPECTED TONS OF CANE/FIELD
C*********************************************************************
      DIMENSION NFLDS(10),NWEATHER(7),NOPT(4)
C
C*    ASSUMED NO FREEZE, HAND HARVEST,ALL FIELDS ARE 32 ACRES****
C
      MAX = -99999
      NTON=0
      NNZ=0
      NGC=0
      NSURP=0
      NFLDS(5)=0
      NWEATHER(6)=0
      IF (NFLDS(2).EQ.0) NFLDS(2)=1
      NFLDS(9)=32
      NFLDS(2)=2
C
C*    ********* COST DATA INFORMATION *************************
C
C*              C1 = VARIABLE GROWING COST PER ACRE
C*              C2 = HARVESTING COST PER TON OF CANE
C*              C3 = TRANSPORTATION COST PER TON OF CANE
C*              C4 = PROCESSING COST PER TON OF CANE
```

```
      GO TO (21,23,24,25,26),NOPT(4)
21    COST = TON*PRI - GC
      GO TO 29
23    COST = Z*PRI - GC
      GO TO 29
24    COST = SURP-GC
      GO TO 29
25    COST = TON
      GO TO 29
26    COST = Z
29    IF (NOPT(2).EQ.0) GO TO 33
      IF (COST.GT.MAX) THEN
      MAX=COST
      NVAR=K1
      NTON=TON
      NNZ=Z
      NGC=GC
      NSURP=SURP
      ENDIF
      PRS=0
      TON= 0
22    CONTINUE
      COST=MAX
      TON=NTON
      Z  =NNZ
      GC=NGC
      SURP=NSURP
33    COST=-COST
      RETURN
      END
C***********************************************************************
      SUBROUTINE OPT(NODES,NARCS,NI,NJ,NHI,NLO,NCOST,NFLO,NPI,NA,NB,
     *               NFEAS)
C***********************************************************************
C*  MINIMUM COST NETWORK FLOW ALGORITHM (OUT OF KILTER).                *
C*                                                                      *
C*  NODES = NUMBER OF NODES                                             *
C*  NARCS = NUMBER OF ARCS                                              *
C*  FOR EACH ARC J                                                      *
C*      NI(J) = BEGINNING NODE                                          *
C*      NJ(J) = ENDING NODE                                             *
C*      NHI(J) = UPPER CAPACITY                                         *
C*      NLO(J) = LOWER CAPACITY                                         *
C*      NCOST(J) = COST                                                 *
C*      NFLO(J) = FLOW  (MUST INITIALIZE)                               *
C*  FOR EACH NODE I                                                     *
C*      NPI(I) = NODE NUMBER  (DO NOT INITIALIZE)                       *
C*      NA(I) & NB(I) USED BY PROGRAM FOR LABELLING.                    *
C***********************************************************************
      DIMENSION NI(5000),NJ(5000),NCOST(5000),NFLO(5000),NA(950),NB(950)
     *          ,NPI(950),NLO(5000),NHI(5000)
      DO 1 I=1,NODES
      NPI(I)=0
      NA(I)=99999
      NB(I)=99999
1     CONTINUE
      NAOK=0
      INF=999999999
C***********************************************************************
      PRINT *,'I AM OPTIMIZING'
2     DO 3 I=1,NARCS
      NFL=NFLO(I)
      M=NI(I)
```

```
C*    ***********************************************************
C
      PZ = 480
      FC = 275
      C1 = 450
      C2 = 7.15
      C3 = 0.35 + 0.15*NFLDS(10)*1.5
      C4 = 6.54
C*************************************************************
C
      PRS1=7.64 - 0.02*NFLDS(6) - 0.02*NFLDS(3) - 0.009*NWEATHER(3)
     * -0.65*N6 + 0.30*N6**2  - 0.03*N6**3 + 0.28*NWEATHER(1)
     * -0.10*10 + 0.01*NFLDS(2)
C
      TON1=-41.46 + 0.44*NFLDS(6)  - 0.06*NFLDS(3) + 0.08*NWEATHER(3)
     * +4.75*N6 - 0.62*N6**2  + 1.36*NWEATHER(1) - 1.11*10
     * -4.05*NFLDS(2)
C
      K1=NFLDS(1)
      NVAR=K1
      DO 22 K=1,5
      IF (NOPT(2).EQ.0) GO TO 15
      K1=K
15    PRS=PRS1.
      TON=TON1
      GO TO (1,2,3,4,5),K1
1     PRS=PRS - 0.18
      TON=TON + 40.14 - 4.17*N6 - 9.09*NFLDS(2)
      C4 = C4*1.16
      C1 = C1*0.90
      GO TO 20
2     PRS= PRS + 0.13*N6
      TON = TON + 5 - 1.8*NFLDS(2)
      C4= C4*1.28
      C1= C1*0.8
      GO TO 20
3     PRS = PRS - 0.56 + 0.12*N6
      TON = TON - 2.68 + 3.81*NFLDS(2)
      C4  = C4*1.28
      C1  = C1*0.7
      GO TO 20
4     PRS = PRS - 0.20 - 0.04*N6
      TON = TON - 2.61 + 1.99*NFLDS(2)
      C4  = C4*1.28
      C1  = C1*1.1
      GO TO 20
5     C4  = C4*1.0
20    K2=NFLDS(4)
      GO TO (30,6,7,8,9),K2
6     PRS = PRS + 0.38
      TON = TON - 1.9
      GO TO 30
7     PRS = PRS + 0.48
      GO TO 30
8     TON = TON - 3.3
      GO TO 30
9     PRS = PRS + 0.14
      TON = TON + 5.5
      GO TO 30
30    TON = TON*NFLDS(9)
      Z   = PRS*TON*0.01
      SURP= PZ*Z - (C2+C3+C4)*TON
      GC= (C1+FC)*NFLDS(9)
```

```
      N=NJ(I)
      NC=NCOST(I)+NPI(M)-NPI(N)
      IF(NFL.LT.NLO(I))                 GO TO 4
      IF(NFL.LT.NHI(I).AND.NC.LT.0)     GO TO 4
      IF(NFL.GT.NHI(I))                 GO TO 5
      IF(NFL.GT.NLO(I).AND.NC.GT.0)     GO TO 5
3     CONTINUE
      GO TO 23
4     NSRC=N
      NSNK=M
      NE=1
      GO TO 6
5     NSRC=M
      NSNK=N
      NE=-1
6     IF(I.EQ.NAOK.AND.NA(NSRC).NE.0) GO TO 8
      NAOK=I
      DO 7 J=1,NODES
      NA(J)=0
      NB(J)=0
7     CONTINUE
      NA(NSRC)=NSNK*NE
      NB(NSRC)=NAOK*NE
8     NCOK=NC
9     LAB=0
C*********************************************************************
      DO 10 J=1,NARCS
      M=NI(J)
      N=NJ(J)
      IF(NA(M).EQ.0.AND.NA(N).EQ.0) GO TO 10
      IF(NA(M).NE.0.AND.NA(N).NE.0) GO TO 10
      NC=NCOST(J)+NPI(M)-NPI(N)
      NFL=NFLO(J)
      IF(NA(M) EQ.0) GO TO 11
      IF(NFL.GE.NHI(J))                 GO TO 10
      IF(NFL.GE.NLO(J).AND.NC.GT.0)     GO TO 10
      NA(N)=M
      NB(N)=J
      GO TO 12
11    IF(NFL.LE.NLO(J))                 GO TO 10
      IF(NFL.LE.NHI(J).AND.NC.LT.0)     GO TO 10
      NA(M)=-N
      NB(M)=-J
12    LAB=1
      IF(NA(NSNK).NE.0) GO TO 18
10    CONTINUE
      IF(LAB.NE.0) GO TO 9
      NDEL=INF
C*********************************************************************
      DO 14 K=1,NARCS
      M=NI(K)
      N=NJ(K)
      IF(NA(M).EQ.0.AND.NA(N).EQ.0) GO TO 14
      IF(NA(M).NE.0.AND.NA(N).NE.0) GO TO 14
      NC=NCOST(K)+NPI(M)-NPI(N)
      NFL=NFLO(K)
      IF(NA(N).EQ.0.AND.NFL.LT.NHI(K)) NDEL=MIN0(NDEL,NC)
      IF(NA(N).NE.0.AND.NFL.GT.NLO(K)) NDEL=MIN0(NDEL,-NC)
14    CONTINUE
      IF(NDEL.EQ.INF.AND.(NFLO(NAOK).EQ.NHI(NAOK).OR.NFLO(NAOK).EQ.
     *   NLO(NAOK))) NDEL=IABS(NCOK)
      IF(NDEL.LT.INF) GO TO 16
      NFEAS=0
```

```
      RETURN
16    DO 17 J=1,NODES
      IF(NA(J).EQ.0) NPI(J)=NPI(J)+NDEL
17    CONTINUE
      GO TO 2
18    NEPS=INF
      NIX=NSRC
19    NJX=IABS(NA(NIX))
      NBNIX=NB(NIX)
      KX=IABS(NBNIX)
      NFL=NFLO(KX)
                      MX=0
      IF(NBNIX.LT.0) MX=-1
      IF(NBNIX.GT.0) MX=1
      NC=NCOST(KX)-IABS(NPI(NIX)-NPI(NJX))*MX
      IF(NBNIX.LT.0) GO TO 20
      IF(NC.GT.0.AND.NFL.LT.NLO(KX)) NEPS=MINO(NEPS,NLO(KX)-NFL)
      IF(NC.LE.0.AND.NFL.LT.NHI(KX)) NEPS=MINO(NEPS,NHI(KX)-NFL)
      GO TO 21
20    IF(NC.LT.0.AND.NFL.GT.NHI(KX)) NEPS=MINO(NEPS,NFL-NHI(KX))
      IF(NC.GE.0.AND.NFL.GT.NLO(KX)) NEPS=MINO(NEPS,NFL-NLO(KX))
21    NIX=NJX
      IF(NIX.NE.NSRC) GO TO 19
22    NJX=IABS(NA(NIX))
      NBNIX=NB(NIX)
      KX=IABS(NBNIX)
                      MX=0
      IF(NBNIX.LT.0) MX=-1
      IF(NBNIX.GT.0) MX=1
      NFLO(KX)=NFLO(KX)+NEPS*MX
      NIX=NJX
      IF(NIX.NE.NSRC) GO TO 22
      NAOK=0
      GO TO 2
23    NFEAS=1
24    RETURN
      END
```

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BIOGRAPHICAL SKETCH

Rigoberto Lopez was born on December 16, 1957, in Managua, Nicaragua, where he spent a typical childhood. After high school graduation from La Salle Institute, he entered the Agricultural Panamerican School in Honduras to study general agriculture. There, he graduated in the top third in 1977 and was awarded a full scholarship which he used to complete a B.S. with high honors in the Food and Resource Economics Department of the University of Florida in 1979. In September 1979, he entered the graduate program in the same department where he will receive a Ph.D. in August 1983.

Among other honors, Mr. Lopez has been elected to Gamma Sigma Delta, Alpha Zeta and Phi Kappa Phi. In 1981 he was nominated Outstanding Graduate Student by Alpha Zeta. In 1982 he was President of the Graduate Student Organization of the Food and Resource Economics Department of the University of Florida. In the same year he represented the College of Agriculture in the Graduate Advisory Council and he was also recognized by University President Robert Marston for Outstanding Student Contribution. He is a member of the American Agricultural Economics Association and of the American Economics Association.

Beginning in June 1983, Dr. Lopez will be in Strasbourg, France.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1983

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